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ANALYSIS OF THE INFLUENCE OF BIOMECHANICAL AND ANTHROPOMETRICAL FACTORS ON THE PERFORMANCE OF GOLF SWING

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SOMMARIO

Lo swing del golf è un gesto che implica la generazione di movimento e forze da parte di tutto il sistema corporeo del golfista.
Un'analisi del gesto di swing deve essere caratterizzata da un duplice approccio:

- analisi della biomeccanica del movimento del golfista
- analisi delle caratteristiche antropometriche del golfista

Considerando entrambi questi aspetti, si può ottenere una valutazione completa e valida della performance del giocatore di golf. Questo studio si propone come obiettivo l'analisi di tutti i parametri coinvolti nell'elaborazione del gesto di swing e della loro influenza sulla realizzazione del movimento, in modo da fornire al golfista uno strumento utile per migliorare performance e tecnica.

Il presente lavoro è stato effettuato in collaborazione tra il Laboratorio di Analisi della Postura e del Movimento "Luigi Divieti" del Politecnico di Milano e l'Instituto de Biomecánica de Valencia, dell'Universidad Politécnica de Valencia.
Come soggetti di studio, sono stati analizzati dieci giocatori semi-professionali appartenenti alla Escuela de Alto Rendimiento de la Federación Valenciana, di età compresa tra i 17 e i 23 anni, con un range di handicap tra -1.7 e 5.

In primis è stata realizzata un'analisi antropometrica dei golfisti: attraverso l'utilizzo di uno Scanner 3D sono state rilevate tutte le grandezze relative alle dimensioni e le altezze di tutti i principali segmenti corporei. Diametri ossei, perimetri muscolari e spessore della pliche corporea sono invece stati rilevati con strumentazione supplementare quale segmometro, metro e plicometro. Da queste misure sono stati poi ottenuti i somatotipi dei soggetti, seguendo il sistema di misura di ISAK basato sul metodo di Heath-Carter.

In secondo luogo, si è sviluppata un'analisi biomeccanica dei giocatori attraverso un sistema di fotogrammetria costituito da dieci telecamere con frequenza di acquisizione pari a 250 Hz associato a due piattaforme dinamometriche. Per ogni giocatore, sono state acquisite cinque misure del gesto di swing effettuato con un driver appositamente progettato in base alle caratteristiche antropometriche dei giocatori. Dalla suddetta analisi,

tramite la realizzazione di un modello biomeccanico per l'implementazione dei dati, sono state rilevate numerose variabili cinematiche e cinetiche: gli angoli assunti dalle diverse articolazioni durante il movimento di swing, le velocità angolari dei segmenti corporei, i momenti articolari, le forze di reazione al terreno e i relativi momenti, i tempi di realizzazione del gesto e infine gli spostamenti del centro di pressione. Per una migliore analisi del gesto di swing, questo è stato diviso in sette fasi differenti, per ognuna delle quali sono state rilevate tutte le variabili biomeccaniche corrispondenti.

Una volta acquisiti ed elaborati tutti i parametri antropometrici e biomeccanici, i dati sono stati analizzati tramite uno studio statistico. La valutazione statistica si è effettuata da una parte con l'analisi descrittiva dei dati, e dall'altra con l'analisi delle correlazioni esistenti tra parametri antropometrici, biomeccanici, e di rendimento. Come fattori di rendimento sono stati scelti:

1. velocità della testa della mazza
2. angolo orizzontale di lancio della palla
3. handicap del golfista

I fattori che consentono di valutare la performance di un tiro in una partita di golf sono la distanza raggiunta dalla palla e la sua direzione. Pertanto, la velocità della testa della mazza così come l'angolo di lancio della palla, essendo fortemente correlati con queste due grandezze, sono stati considerati come parametri di rendimento. L'handicap invece, essendo un indicatore della bravura del golfista relazionato con la sua capacità di mettere in buca la palla nel minor numero di colpi, è stato assunto come parametro di misura dell'abilità del golfista. Per la correlazione statistica, sono state considerate significative le relazioni aventi un coefficiente di correlazione di Pearson ≥ 0.45 e un p-value < 0.001.
I risultati ottenuti hanno dimostrato che:

- I parametri di rendimento sono significativamente influenzati dal rango di movimento dei segmenti corporei del golfista nell'atto di esecuzione dello swing. In particolare, è stato notato come diversi tipi di allenamenti influenzino effettivamente i parametri biomeccanici, e quindi la loro correlazione con gli indicatori di performance.

- Le caratteristiche fisiche del soggetto influenzano effettivamente la sua capacità di generare forza nel lancio, condizione rilevabile attraverso la valutazione della velocità della testa della mazza. Soggetti con somatotipi diversi, e in particolare piu mesomorfi, hanno infatti dimostrato di ottenere una maggiore velocità di lancio, legata alla maggiore muscolatura del giocatore.
- Somatotipi diversi, infine, hanno dimostrato differenze nel movimento di esecuzione dello swing: i soggetti più ectomorfi risultano avere un rango di movimento della parte alta del corpo che sfrutta l'altezza, mentre i più endomorfi sembrano avere un maggior movimento di pelvis e tronco dovuto alla minore muscolatura. I parametri biomeccanici, inoltre, risultano essere significativamente influenzati da massa e altezza del golfista.

Il presente lavoro, quindi, dimostra l'importanza dell'analisi sia antropometrica che biomeccanica nello studio del gesto del swing nel golf, e costituisce uno studio preliminare alla determinazione di un gesto "ottimale" di swing che possa essere considerato da golfisti e allenatori come un utile strumento di valutazione della performance nel golf.

ABSTRACT

Golf is a very demanding physical game and the golf "swing" is a complex movement that involves the whole body.
An analysis of the gesture of swing must be characterized by a double approach:

- analysis of the biomechanics of golfer's movement
- analysis of the anthropometric characteristics of the golfer

Considering both these aspects, it can be obtained a complete and valid assessment of the golfer's performance. This study aims to analyse all the parameters involved in the swing gesture and investigate their influence on the realization of the movement, in order to provide the golfer with an useful tool to improve performance and technique.

The present study was developed in cooperation between the Laboratory of Postural and Motion Analysis "Luigi Divieti" of Politecnico of Milan and the Biomechanical Institute of Valencia (IBV) of Universidad Politécnica of Valencia.
In this study, 10 semi-professional golf players of the school of high performance of the Federación Valenciana were analyzed, aged between 17 and 23 years, with a range of handicap among -1.7 and 5, all of them right-handed.

First of all, an anthropometric analysis of the golfers has been realized: through the use of a Scanner 3D all the principal dimensions and heights of body segments have been detected. Osseous diameters, muscular perimeters and thickness of skin folds have been measured with additional instruments: segmometer, plicometer and tape measure. The measurements made with this complementary instrumentation provided additional information for the characterization of the somatotype, which was obtained following the ISAK procedure.

In addition, it has been developed a biomechanical analysis of players through a photogrammetric system consisting of ten cameras with a sample frequency of 250 Hz associated with two dynamometric platforms. For each player, five measures of the movement of swing were carried out with a driver specifically planned according to the

anthropometric characteristics of the golfer. From this analysis, through the realization of a biomechanical model for the implementation of the data, numerous variables kinematic and kinetic have been detected: angles described by the various joints during movement of swing, angular velocities of the body segments, articular torques, ground reaction forces and relative moments, times of the main swing phases and finally center of pressure displacements. In this study, the swing movement has been divided in seven essential parts, for each of them all corresponding biomechanical variables have been detected.

Once acquired and processed all anthropometric and biomechanical variables, the data were analyzed by a statistical study. The statistical assessment consisted on the one hand in a descriptive analysis of the data and on the other hand in the analysis of the correlations between anthropometric, biomechanical, and performance parameters. As performance factors have been chosen:

1. Club head speed
2. Horizontal angle of delivering the ball
3. Golfer's handicap

Factors influencing the performance evaluation of a golf shot are the distance attained by the ball and its direction. Therefore, the club head speed as well as the launch angle have been considered as performing factors, being strongly correlated with these quantities. Handicap instead, is a well known numerical measure of a golfer's ability, related to hitting balls into a series of holes on a course using the fewest number of strokes. For the statistical correlation were considered significant relationships with a Pearson correlation coefficient ≥ 0.45 and a p-value <0.001.
The results have shown that:

- Performance parameters are significantly influenced by the movement of specific body segments detected during the golf swing. Then it could be deduced that training aimed at timing and specifical movements of those segments might have a noticeable influence on performance.
- Physiological capacities may improve the ability of golfers to execute stronger shots during swing, which translates in higher club head velocity. Subjects with different somatotypes produce different club head speed, in particular those with a

higher amount of mesomorphy, characterized by bigger muscles, demonstrated better skill in accelerating the club head.

- Different executions of the swing motion are associated to different somatotypes: more ectomorph subjects have demonstrated to use their height for extending the range of motion of the higher part of the body, while those being characterized by a higher level of endomorphy seam to emphasize the movement of pelvis and trunk. Furthermore, biomechanical parameters are strongly influenced by the golfer's body mass and height.

This thesis shows therefore the importance of carrying out a biomechanical as well an anthropometrical analysis of the swing movement in golf, with the objective of defining its execution. It can be considered as a preliminary study for the definition of an “optimal” swing, furnishing a useful means for golfers and coachers to evaluate many aspects of training and performance in golf.

1. INTRODUCTION

Golf is a sport that is enjoyed by millions of people of all ages and abilities. This may be because golf has no age, anthropometric restrictions, advantages or gender limits associated with it, therefore being a popular activity for most people [14]. Besides, golf is a very demanding physical game, not only in terms of precision and complexity of the golf swing movement, but also in terms of creating explosive power through a wide range of motion [50]. Thus, to analyse the golf swing, a body motion analysis is necessary. The body motion analysis is used in many fields of biomechanics to explore all the aspects of movement.

The present study was developed in cooperation between the Laboratory of Postural and Motion Analysis "Luigi Divieti" of Politecnico of Milan and the Biomechanical Institute of Valencia (IBV) of Universidad Politécnica of Valencia with the aim of offering a functional assessment through the motion analysis to all the golf players that need to improve the technique of "swing" and to obtain a swing movement more suited to their anthropometric characteristics and needs. Moreover, the outcome of the assessment and a posterior analysis can be useful to provide objective variables (anthropometric, kinematic and kinetic) for the different types of training that the player needs to perform. These variables may influence in getting more performance with the gesture.

Therefore, the main objectives of the present study are:

1. To develop and analyse the correlation between the biomechanical motion of the swing, the anthropometrical characteristics of the golfer and the sportive performance.
2. To obtain biomechanical criteria to improve the swing motion and thus the performance of the golfers, enhancing the precision and length of the shots.
3. To know the aspects that the golfer should improve in order to enhance his swing technique, this will define a set of exercises customized for each golfer.
4. To adapt an "optimal" golf swing for each golfer, based on his anthropometrical characteristics, this will enable to the player improving the execution of the swing movement.

To reach these goals, the work has been structured in different phases:

1. **Part 1 - Literature review:** the current scientific literature concerning the biomechanical analysis of golf swing was analysed. A definition of the different parameters studied by the researchers and of the different methods used to conduct the analyses was presented. Some limitations were found analysing the state of art: they were examined to better define the objectives of this project.
2. **Part 2 - Determination of cxperimental methodology:**
   - ***2.1. Definition of the study sample:*** the inclusion criteria of the participants were defined. Ten semi-professional golfers were recruited to participate to the project.
   - **2.2.** ***Definition of the movement to analyse***: the movement of swing was studied dividing it into seven different phases that were analyzed separately.
   - **2.3.** ***Laboratory set-up:*** the analysis of the golf players was carried out in the laboratory of biomechanical analysis of IBV. It was determined the instrumentation considered necessary for the assessment as well as its optimal disposition to conduct the golf swing motion analysis.
3. **Part 3 - Data collection:** all the measures necessaries for the analysis of golf swing were realised in this phase. Anthropometric data of the players were obtained with a 3D scan, a plicometer, a tape measure and a segmometer. Then, kinetic and kinematic variables were collected through the photogrammetric and dynamometric system and digytalized. All the data were then processed to be statistically elaborated in the following phase.
4. **Part 4 - Statistical analysis:** the statistical study of the data consisted on the one hand in a descriptive analysis of the measured variables, and on the other hand in a study of the relation between the different types of parameters (anthropometrical, biomechanical and performing factors), by means the technique of Correlation.
5. **Part 5 - Analysis of results and conclusions:** the results found were critically reviewed. They were compared with the results of similar studies, and then the limitations of the present work and the future developments were discussed.

Project phases	Weeks																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
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Part 4 - Statistical analysis																															
Part 5 - Analysis of results and discussion																															

Table 1: Gant diagram of the Work Plan

2. STATE OF ART

2.1 HISTORICAL BACKGROUND OF THE THE ANALYSIS OF GOLF SWING

Golf is played by 10-20% of the adult population in most countries [47], with estimates of more than 55 million golfers around the world [49]. According to Golf20/20 [47], golfers and golf enthusiasts spend globally 76 billion dollars on the game for year.

As can be seen in the following tables, the number of golf players in Italy and Spain is increasing in the last years, which represents the evolution of number of golfers from 1999 to 2010:

INCREMENT OF LICENSES IN ITALY 1999-2010			
YEAR	**LICENSES**	**ABSOLUTE INCREASE**	**PERCENTAGE INCREASE [%]**
1999	56.478		
2000	59.518	3.040	5,11
2001	64.027	4.509	7,04
2002	67.591	3.564	5,27
2003	72.418	4.827	6,67
2004	77.208	4.790	6,20
2005	81.591	4.383	5,37
2006	84.567	2.976	3,52
2007	92.233	7.666	8,31
2008	96.022	3.789	3,95
2009	100.317	4.295	4,28
2010	100.548	231	0,23

Table 2: Number of licenses in Italy from 1999 to 2010 with absolute and percentage increases per year [13].

INCREMENT OF LICENSES IN SPAIN 1999-2010			
YEAR	**LICENSES**	**ABSOLUTE INCREASE**	**PERCENTAGE INCREASE [%]**
1999	137.752	15.071	12,3
2000	154.857	17.105	12,4
2001	177.409	22.552	14,6
2002	199.516	22.107	12,5
2003	222.200	22.684	11,4
2004	241.618	19.418	8,7
2005	258.081	16.463	6,8
2006	279.660	21.579	8,4
2007	300.047	20.387	7,3
2008	318.331	18.284	6,1
2009	333.818	15.487	4,9
2010	338.588	4.470	1,4

Table 3: Number of licenses in Spain from 1999 to 2010 with absolute and percentage increases per year [39].

Until 2010, it is reported that in Spain there were around 338.600 licenses [39] while in Italy the number of regular golfers was around 100.500 [13]. The number of golf courses registered in Spain was 416 [39], while in Italy was 414 [42].

Over the years, there have been many published golf studies. Due to the fact that the golf shot is one of the most difficult biomechanical motions to execute in sport, a detailed understanding of the mechanics of the swing would be beneficial to the golfer and teached [49]. The golf swing has been investigated scientifically for nearly 40 years, ever since the ground-breaking work carried out by the Royal Society Golf Group [49], which set out to establish the mathematical and mechanical parameters underlying performance in golf.

Different types of analyses were developed, focusing in different aspects of the swing motion. All these methods have been reviewed and are reported in the following paragraph. The aim of this part is to furnish a complete analysis of the current literature, in order to develop a study which can provide a complete analysis of the movement of swing, taking into consideration even those aspects that were not examined before.

2.2 LITERATURE REVIEW

Over the years, golf biomechanics has been the object of analysis of many studies. The role of biomechanics in maximizing golf performance was studied by Hume et al. in 2005 [21]. They analyzed what golf biomechanics is and how it is related with the improvement of accuracy and distance of a golf shot. According to them, golf biomechanics aplies the principles and technique of mechanics to the structure and function of the golfer in an effort to improve golf technique and performance. It has been used in an attempt to characterize an "ideal" golf swing with the aim of improving performance and reducing risk of golf-related injuries. It provides qualitative and quantitative evidence of body angles, joint forces and moments, and muscle activity patterns.

The biomechanical analysis of golf carried out in the last years can be divided into 3 main fields of studies, respectively focused on:

1. the golf ball
2. the golf club
3. the golf player, more specifically divided into:
    a) body motion analysis
    b) anthropometric analysis

In the present work, a review of these types of studies and their applications is developed.

2.2.1 Studies focused on the golf ball

The aim of this type of studies is to characterize the launch of the ball in order to evaluate the golf swing. To develop a golf ball launch analysis, the main parameters that were investigated are:

- Ball Velocity
- Vertical Launch Angle
- Horizontal Launch Angle
- Spin Rate
- Carry Distance (the distance from which a ball is struck to when it first lands)
- Total Distance (the carry distance plus the roll distance).

A complete analysis of all of these parameters was developed by Lephart et al. [27] and Myers et al. [34].The main variable of interest in this study was the ball velocity given that

this variable was measured directly by the ball flight sensor from the point of ball impact until the ball hits the protective backstop. Also Healy et al. [18] and Chu et al. [8] considered the ball velocity as the driving performance variable of their studies.

The systems used to investigate all these aspects of the ball launch were:

- The Vector Launch System (Accusport, Inc., Winston-Salem, NC) used by Lephart et al. [27], to collect golf ball launch data during the biomechanical analysis. The system used a microphone to determine impact and a high-speed camera to record two images of the ball after impact. The system identified the vertical line on the ball for each image and used internal algorithms to compare the line positions to measure ball velocity, launch angle, and backspin rate and to calculate club head velocity, carry distance, and total distance.
- The Flight Scope Sim Sensor (EDH, Ltd., South Africa) integrated with AboutGolf (AboutGolf Limited, Maumee, OH) simulation software, used by Chu et al. [8] and Myers et al. [34]. This system applies three-dimensional phased array microwave technology that operates at 7 kHz to track ball flight from club impact until impact with a screen 5 m away. Ball velocity, vertical launch angle, horizontal launch angle, spin rates, carry distance, and total distance are derived from ball tracking data.

The golf ball launch analysis has some advantages:

- rapid measurements
- instantaneous feedback to the golfer
- experimental tests developed on the golf field

Despite of this, this kind of analysis does not provide any information about the golfer. A correlation between ball launch parameters and golfers' execution of swing cannot be obtained with an analysis focused only on the golf ball. Thus, improvements in golf techniques and training seem difficult without studying other aspects of the golf swing.

2.2.2 Studies focused on the golf club

These studies matched the characteristics of the golf club to the swing parameters in order to define the optimal golf club. Features taken into consideration were:

- club head speed
- shaft length
- head weight
- club weight
- frequency of shaft
- shaft flexibility
- club head deflection
- trajectory of the club

Club head speed was taken as a performing factor by the majority of the examined authors. The reason is that club head speed is related to the ball flight distance and direction of flight, usually taken as indexes to evaluate the performance of a shot. Hume et al. [21] reported that most of biomechanics research in maximizing ball displacements investigated the factors related to the velocity of club head, since there is a direct proportionality between the displacement of golf shot and the club head speed at the moment of impact. According to this, Fradkin et al. [14] determined that club head speed at impacts was a valid measure of golf performance investigating the relationship between club head speed and handicap. Handicap, in fact, refers to a numerical representation of a golfer's playing ability: the lower a golfer's handicap, the better the golfer is. The behaviour shown in Fig. 1 of decreasing club head speed with increasing handicap seems reasonable at large scale, although more dispersive results are obtained if a more limited range of the handicap scale is taken under consideration (as explained in Par. 5).

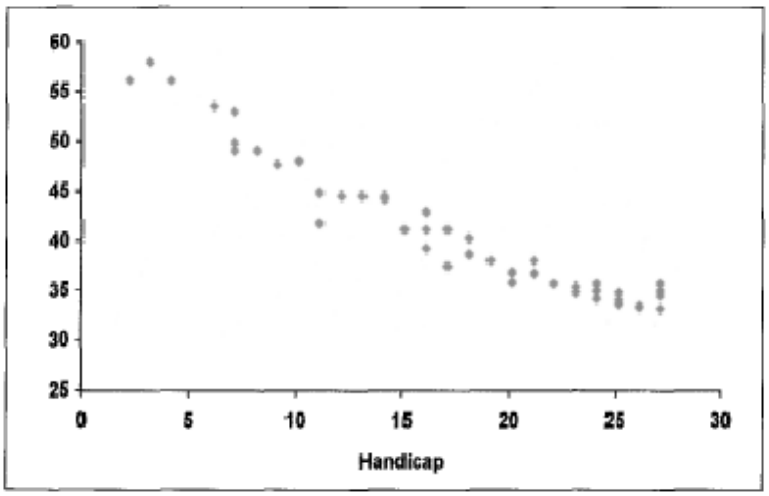


Fig. 1: Mean club head speed vs handicap of golfers [1]

The importance of the shaft length of a golf club was analyzed Mizoguchi et al.[33]. They matched the shaft length to an individual's golf swing motion in order to develop a higher performance club for longer driving distances. They used club head speed as performing factor. Results showed that increases in shaft length did in fact create an increase in the head speed at the impact in all subjects. Therefore, it was confirmed in this study that lengthening the shaft of a golf club is effective to increase the driving distance.

The role of shaft flexibility and its relation with club head speed was studied by MacKenzie [29]. He considered that the predominant factor in generating maximum ball speed is attaining maximum club head speed at impact, and theoretically, club head speed can be increased without changing the mechanics of the golfer's swing, if the behaviour of the golf shaft is optimized. During the downswing, the shaft bends backwards storing strain energy. This energy could then be converted to kinetic energy at the impact. This kinetic energy would result in additional club head speed. The launch angle and the spin rate of the golf ball after impact are strongly influenced by the orientation of the club head at impact. The orientation of the club head can be changed by altering the stiffness of the shaft. Therefore, theoretically, the optimal launch angle and spin rate can be generated by finding the shaft stiffness that produces the optimal club head orientation at impact.

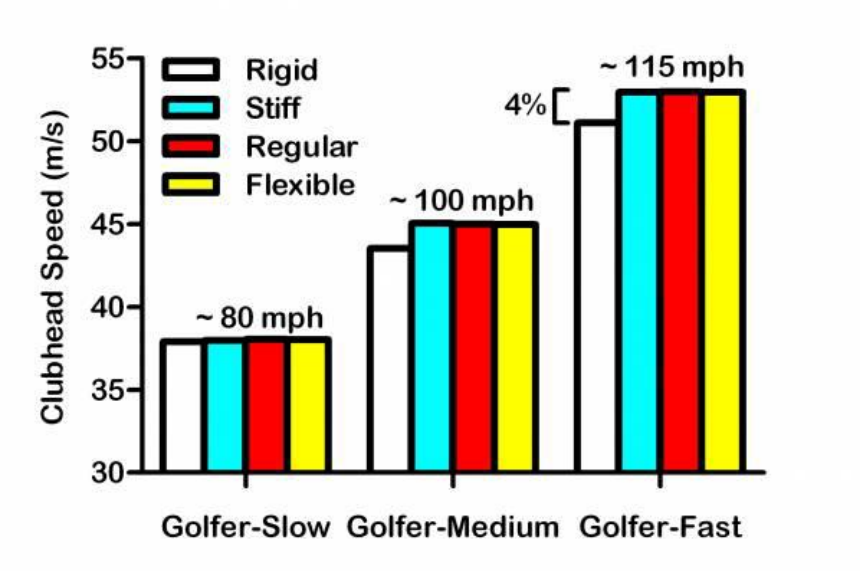


Fig. 2: Club head speed at impact for 12 optimized golfer-club models [29].

In Fig. 2, changes in club head speed caused by changes in shaft flexibility are represented. The results were evaluated for golfers that generate three different levels of club head speed (i.e. Golfer-Slow ~ 35 m/s, Golfer-Medium ~ 43 m/s, and Golfer-Fast ~ 50 m/s).

Different methods were implemented to study the role of golf club in improving golf performances.

Club head speed was evaluated by Fradkin et al.[14] with a stationary high-speed camera. The camera utilised in this experiment was the RedlakeMotionScope PCI 500 and was operated at a frequency of 250Hz (125fps) and a shutter speed of 1/500 seconds. Teu et al. [46], instead, presented a new method of club head speed analysis using dual Euler angles and its application in studying rotational contribution from upper extremity segments to club head speed during a golf swing.

To carry out the analysis of the golf club shaft length the system represented in Fig. 3 was implemented by Mizoguchi et al. [33]:

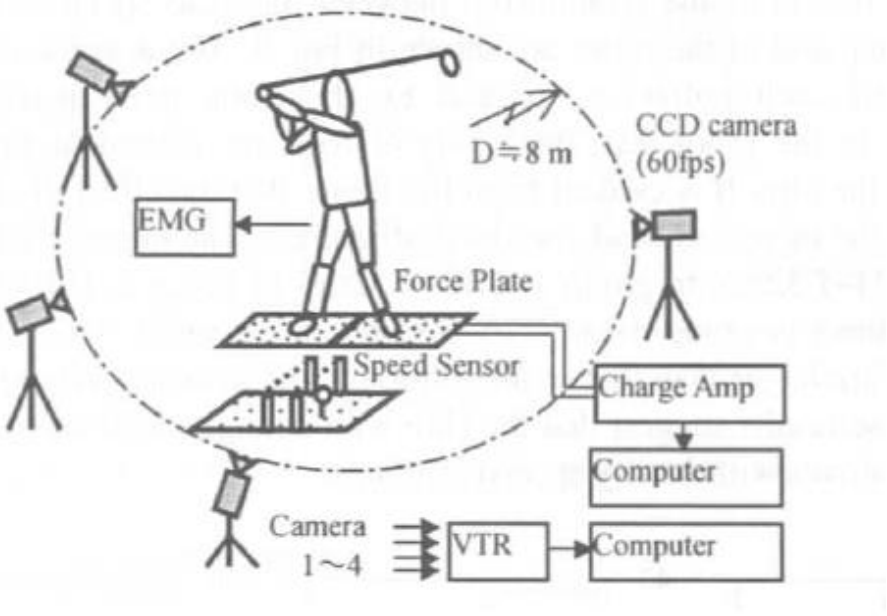


Fig. 3: Experimental Set Up [33]

The system was composed of:

- Sensor on the club head speed by a pair of laser type sensor head
- 3D motion analysis system using four cameras
- Two force platforms installed on the floor in line
- Surface electromyogram measurement system

To evaluate shaft flexibility, MacKenzie [29] developed a method consisting in representing a mathematical model of a golfer using a six-segment (torso, arm, and four club segments), 3D, linked system. The purpose of the golfer portion of the model was to generate realistic kinetic profiles (forces and torques) on the club segment during the downswing.

Studying club characteristics can provide great improvements in golf performances. Hume et al. [21] affirmed that to maximize ball displacements, the golfer must maximize the angular velocity of the club head and the length of the club arm system at impact. MacKenzie [29] reported that maximum shot distance is achieved by generating the highest possible ball speed while imparting the optimal launch angle and spin rate for the particular ball speed attained. Shaft stiffness influences all three of these parameters. Moreover, the study of Mizoguchi [33] highlighted that the length of the shaft can consent to increase the driving distances without any specific physical training.

Nevertheless, a study aimed to improve the characteristics of the club, as said before for the studies of the golf ball, cannot have an impact on the golfers' training and on their execution of swing. Thus, it cannot have a specific role in preventing injuries or in improving individual golfer's techniques.

2.2.3 Studies focused on the golf player

The main part of the current research related to the biomechanical analysis of golf is focused on the player. This kind of studies can be mainly divided into four different types of analysis:

1. Kinematic Analyses
2. Kinetic Analyses
3. Kinematic and Kinetic Analyses
4. Anthropometric Analysis

2.2.3.1 Kinematic Analysis

The main parameters involved with this investigation were:

a) the **Range of Motion (ROM)** of all the principal joint systems was analyzed by different authors: X factor, shoulder, arm, elbow, wrist, trunk, pelvis, hip and knee angles and angular velocities were calculated as kinematic variables.

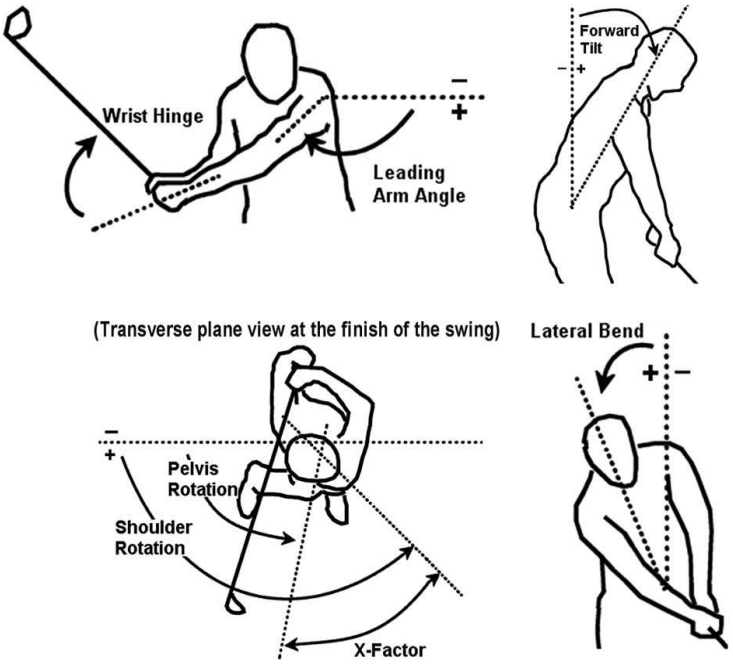


Fig. 4: Kinematic variables selected in the study of Chu et al. [8]

In particular:

- **Wrist joint angle and rotational velocity** were considered important factors in generating club head velocity and orienting the club face. It was reported that the range of motion of wrist (as well as its torques too, in a kinetic perspective) is important in generating club head speed and orienting club face, more than hands speed [36]. Also the linear velocity and acceleration of the hands were studied by Nesbit[36].

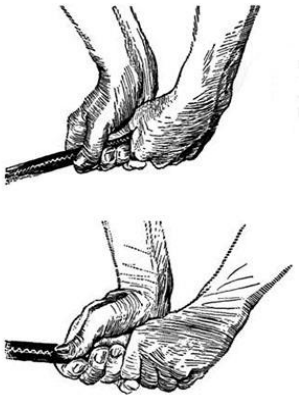


Fig. 5: Wrist motion during the golf swing

- The importance of **X-Factor** was highlighted in literature: the "X-Factor" is a popular term referred to the relative rotation of shoulders with respect to hips

during the golf swing. Many authors emphasized that neither upper torso nor pelvis rotation by themselves but rather the X-Factor was considered significant [8][30]. Since the 1960s, a “modern” golf swing focusing on the X-Factor started to replace the “classic” swing that is focused on both the upper torso and pelvis rotations, as the modern swing generates greater power for longer shot [31].

Fig. 6: Representation of the X-Factor

- **Angular velocities** of body segments were calculated and also reported in some studies with respect to the local coordinate systems embedded in the segments. An example of average sequencing graph for the players is shown in Fig. 7 [34]:

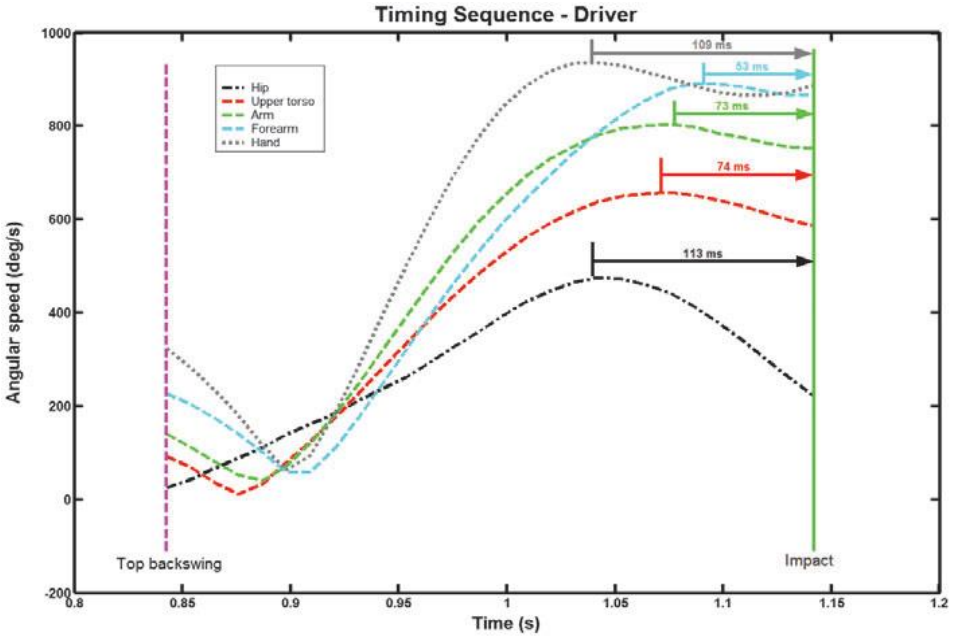


Fig. 7: Angular Speeds of five body segments (Pelvis, Upper Torso, Arm, Forearm and Hand) Between the Top of the Backswing and Impact [35]

b) **Kinetic Chains** were used in literature for the description of the body motion during the swing: most sports medicine and exercise science professionals use this term to describe a sequence or a chain of events that take place in order for an athlete to make the shot. In golf shots, the kinetic chain starts with the movement of legs and hips, followed by the movement of trunk and shoulders, and finishes with hand and wrist motion [21].

Basically, the kinematic analysis is assessed with a 3D motion analysis system. Here the principal techniques used during the last years are reported.

3D photogrammetric system with two video cameras SVHs (sampling frequency of 50 Hz) [17]: the digitalization process is manual for each photogram, using the Kinescan-Digital IBV application. The 3D coordinates are calculated through the DLT method [1]. To localize better the moment of the impact, it is possible to perform a time interpolation to represent a 100 Hz frequency. Even this frequency, is nowadays considered too low to carry out a complete and precise kinematic analysis.

3D photogrammetric system (VICON Oxford Metrics®) composed of six infrared cameras with a sampling frequency of 250 Hz [28]: the shots are executed from a grass carpet towards a net situated 5 meters distant. The biomechanical model is based on 27

body markers and 4 club markers. Compared to more recent studies, the number of cameras seems too small to consent a complete view of the movement.

A twelve camera (250 Hz) motion analysis system (VICON 512 M, Oxford Metrics Ltd, UK) [18]: forty-one reflective spherical markers are placed on anatomical landmarks on the body. This analysis, compared with the others, has a bigger number of cameras working at a higher frequency. In this study, even though a complete method of kinematic analysis is assessed, other types of analyses were not developed: to have a more complete biomechanical analysis of the movement, kinetic and physical parameters should be evaluated.

3D Polhemus Fastrak magnetic tracking system (Polhemus Inc., Colchester, VT) [35]: three dimensional (3D) kinematic data are collected and segment position and orientation data are captured for approximately 2 s for each swing with each sensor sampled at 30 Hz. But 30 Hz seems to be a not appropriate frequency for a precise measure of the golf swing, as underlined before. A four-sensor system is used to provide position and orientation data for a five-segment model of the golfer, which does not consent a detailed analysis of the whole body. Higher-order kinematic data are calculated using standard numerical differentiation procedures.

3D electromagnetic tracking system (Polhemus Liberty) [48]: this system is used to record pelvis, upper torso and hand movements at 240 Hz and the magnitude of the resultant angular velocity vector of each segment is computed. Three sensors are attached to each player to monitor the motion of pelvis, torso and hand, while the other parts of the subjects' body are not analyzed.

A kinematic analysis provides fundamental information related to the swing motion. Nevertheless, it needs to be associated to different analyses, as, firstly, a kinetic study, to evaluate all these important aspects that are not assessed with the considered methods: ground reaction forces, joint torques and postural stability.

2.2.3.2 Kinetic Analysis

With this type of investigation, the main parameters taken into account in the literature examined are:

a) Forces (and their changing rate):

- Vertical Ground Reaction Force (VGRF)
- Antero/posterior GRF
- Medio/lateral GRF
- the magnitude of the golfer/club interaction force

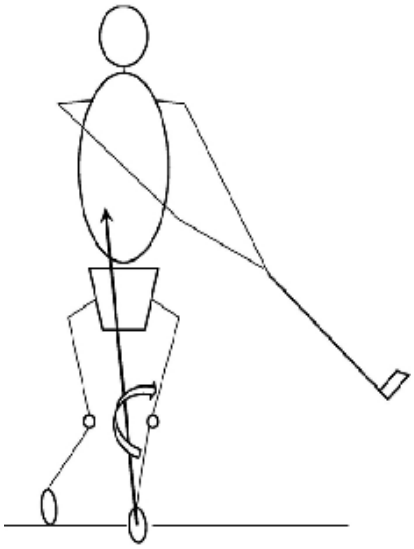


Fig. 8: Representation of GRF and GR torques during the golf swing

b) Postural stability variables: orthogonal and horizontal COP signals were often recorded according to the methods of Goldie et al.[15][16].

c) Torques: there are two types of torques interested in the movement:

- Ground Reaction Torques: these torques were not examined in the selected literature, although an analysis of them can show an interesting relation with the performing parameters.
- Articular torques: torques imposed on the articulations by the weight of the golfer were considered by some authors, as Nesbit [36] and Lephart [27]. In [36] the three components of the golfer/club interaction torque were also studied.

d) Work and power: Nesbit [36] made an energy analysis, calculating the total, linear, and angular components of work and power. The expressions were developed from the analytical equation for the work on a rigid body in three-dimensional motion.

Different techniques were developed to evaluate the kinetic variables.

An analysis of torques and VGRF was made by Nesbit [36], developing a ground surface model to support the golfer. A linear spring-damper system was used to represent the

contact between the feet and the ground, and frictional forces provided traction. Individual force plates were used to measure the vertical reaction forces between the golfer's feet and the ground. The data provided kinetic verification of the model since ground reaction forces were one of the outputs of the model. To correct some approximations related to the model, a torque control function was applied. In this study the torque in the ankle joint imposed by the weight of the golfer on that foot was considered.

Ground Reaction Force data were collected using two Kistlerforce platforms (one under each foot) (KistlerInstrumente AG,Winterthur, Switzerland) operating at 1200 Hz that were synchronized with the cameras by the Peak Motus System in the study of Chu et al.[8].

In the works of Lephart et al. [27] and Sell et al. [43], balance was assessed according to the methods of Goldie et al. [15][16] using a Kistler force plate (Kistler Corporation, Amherst, NY) at a frequency of 100 Hz. Different conditions are experimented to complete the balance test (barefoot, single leg standing test, eyes open and eyes closed test).

A complete kinetic analysis not only has to include the evaluation of all the GRFs and a postural analysis through the assessment of COP displacements, that but it should also provide an study of all the GR Torques generated by the GRF. In the present review, it was difficult to find an analysis that owned all these characteristics.

2.2.3.3 Kinematic and Kinetic Analysis

This analysis matches the two methods examined previously: so, it consists in a combination of a study of kinematic variables, with the information provided by a kinetic analysis. This method consents to study all the aspects that were examined in the review of the Kinematic and Kinetic Analysis of the golf player.

A biomechanical method that combine these two types of analysis was developed by various authors [27][8][43]; it consists in:

Kinematic Analysis: the Peak Motus System v.7.0 (Peak Performance Technologies, Inc., Englewood, CO) is used to collect kinematic data of the golf swing. This system is composed of eight optical cameras (Pulnix Industrial Product Division, Sunnyvale, CA) placed at a distance of 4 m from the golf teeing area. It is possible to evaluate the ranges of motion of the main joint systems using a standard goniometer.

Kinetic Analysis: Ground Reaction Force data were collected in the study of Chu et al. [8] and a Balance Assessment was accomplished by Lephart et al. [27] and Sell et al. [43] according to the techniques explained above.

Moreover, in these last two studies, a strength test was assessed with the Biodex System III Multi-Joint Testing and Rehabilitation System (Biodex Medical Inc., Shirley, NY), while in the study of Chu et al. [8] this test was not executed but anthropometrical measurements of both the lower and upper extremities were developed.

There were some limitations to the studies analyzed, although they carry out a complete biomechanical analysis, correlating kinematic and kinetic parameters with performing factors.

In the study of Chu et al. [8], first, while the performance goal that golfers pursue is the driving distance, in the laboratory setting it could only be estimated with ball velocity. Nevertheless, ball velocity might be affected by the club head velocity, launch angle, and ball spin rate [38]. Due to this fact, other performing factors should be considered. Second, golfers used their own drivers in the testing. Differences in shaft length and flexibility, shape of club head, material and inertial properties might all affect the ball velocity. Third, a balance analysis was not assessed, while it would have been provided necessary information about the postural stability of the players. Postural stability has to be taken into account in a biomechanical analysis aimed to prevent injuries.

In the studies of Lephart et al. [27] and Sell et al. [43] no anthropometrical data were collected. Thus, physical characteristics of the golf players were not considered in the analysis of their performance. Chu et al. [8] effectively made an anthropometrical study, although they did not correlate anthropometrical data with performing or biomechanical factors. Thus, an analysis of how anthropometrical parameters affect the golf performance was not developed.

2.2.3.4 Anthropometric Analysis

Some authors based their studies on the analysis of the influence of anthropometrical factors on the golf performance.

The parameters that were considered in this type of analysis were:

- Height
- Body mass

- Body mass index
- Sum of 4 skinfolds
- Body fat (%)
- Fat mass
- Fat-free mass
- Acromiale-radiale length
- Radiale-stylion length
- Acromiale-stylion length
- Biacromial width
- Chest girth
- Upper arm girth
- Sitting height
- Arm length
- Leg length
- V_{O2max} predicted

To develop the anthropometric analysis, some methods were utilized. In the study of Keogh et al.[25], stretched stature was measured using a standard wall mounted stadiometer. Body mass was measured using a calibrated SECA Atrax 770 electronic scale (Seca, Hamburg, Germany). Skinfolds were measured on the right side of the body using a Slim Guide caliper. Arm segment lengths and shoulder breadth were measured using a Siber-Hegner anthropometer. Girths of the chest and relaxed upper arm were measured using a Lufkin W606PMflexible steel tape. The authors performed a statistical analysis to determine whether a number of selected kinanthropometric variables are correlated to club head velocity and if these variables can distinguish between low-handicap and high-handicap golfers. In this work, though, not all the anthropometrical variables involved in the golf swing motion were assessed. Moreover, no overall parameters like endomorphy ectomorphy and mesomorphy were used.

The methods used in Wells et al. [50], instead, consisted in the assessement of mass and of standing and sitting height by using a Health- O-Meter weighing scale (Health-O-Meter 400S; Sunbeam Products Inc., Boca Raton, Fla). In this study, anthropometric parameters were analytically expressed by means of physical measures and response of the athletes to prescribed stresses. Either in this study, no mention of somatotype quantities was

furnished.. Performance parameters were ball velocity, carry distance and tournament conditions. No measures of club head speed were carried out.

2.3 CONCLUSIONS OF THE LITERATURE REVIEW

From the literature review emerged a lack of these points of observation:

1. The correlation between anthropometric parameters and the biomechanical factors that characterise the swing motion has not been analysed in the literature examined.
2. The influence of the somatotype factors on golf performance and biomechanics has not been assessed in previous studies.
3. Ground Reaction Torques have not been evaluated in the reviewed literature. An analysis of these torques can bring interesting findings for a complete kinetic analysis, especially if done in relation with other kinetic variables as Ground Reaction Forces, Articular Torques and COP displacements.
4. A biomechanical model of the whole body has not been developed: no ROM of head and ankles have been reported and analysed in an integrate way with torques and anthropometric parameters.
5. 3D measurements of the whole body have not been performed. 3D scanners have not been used in the studies examined, although they can provide a detailed description of all the body parts interested in the movement examined.

3. MATERIALS AND METHODS

3.1 STUDY SAMPLE

The study sample was composed of ten subjects, as shown in Table 4. The subjects examined were 10 semi-professional golf players of the school of high performance of the Federación Valenciana de Golf. All of them were confirmed to be right-handed. The age, body mass, height and handicap of the golfers tested are reported in Table 4:

SUBJECT	AGE [years]	BODY MASS [kg]	HEIGHT [cm]	HANDICAP
1	21	78.1	183.6	0.9
2	23	67.4	175.3	-1.7
3	23	79.4	185.7	2.1
4	23	81.6	183.5	2
5	19	95	175.2	3.5
6	23	107.5	173.9	-0.8
7	17	57.4	165.9	3.2
8	21	67.6	165.1	2.7
9	22	86.3	190	4
10	23	79.9	169.9	5

Table 4: Anthropometrical parameters: age, body mass, height and handicap of the golf players

The golf “handicap” indicates player's skill level on a standard course. The handicap number represents the average number of strokes the player would need to add or subtract from his score to reach par on a standard course. The higher the handicap of a player, the poorer the player is relative to those with lower handicaps. The maximum USGA (United States Golf Association) handicap allowed by for men is 36.4 Exact rules relating to handicaps, though, can vary from country to country.

3.1.1 Definition of the somatotype of the golfers

Together with the analysis of the anthropometrical characteristics of the subjects, a characterization of the somatotype of the study sample was carried out. Somatotyping is a system of classifying body types in terms of three categories: endomorphy, mesomorphy and ectomorphy.

Ectomorphy: an ectomorphic person would be tall and thin, with a narrow body, thin arms and legs, little body fat and wiry muscles. In general, ectomorphs rank high on endurance, flexibility and agility.

Mesomorphy: a mesomorphic person would be strongly built, with a broad muscular chest and shoulders, very muscular arms and legs, and little body fat. In general, mesomorphs rank high on strength, endurance, power and agility.

Endomorphy: an endomorphic person is generally stocky, with a large round body, a short thick neck, short arms and legs, and with a tendency to store body fat.

All the somatotype data collected are reported in Appendix 1.

Somatotype was measured using the Heath-Carter measurement system [6], in which ratings for endomorphy, mesomorphy and ectomorphy are calculated using the measurements assessed in the ISAK Manual [23].

The subjects were generally classified on a scale from 1 to 10 in each of the three categories. The three numbers together give a somatotype index. The scores may also be plotted in a shield diagram or somatograph, representing the somatotype on a two dimensional graph. (Fig. 9).

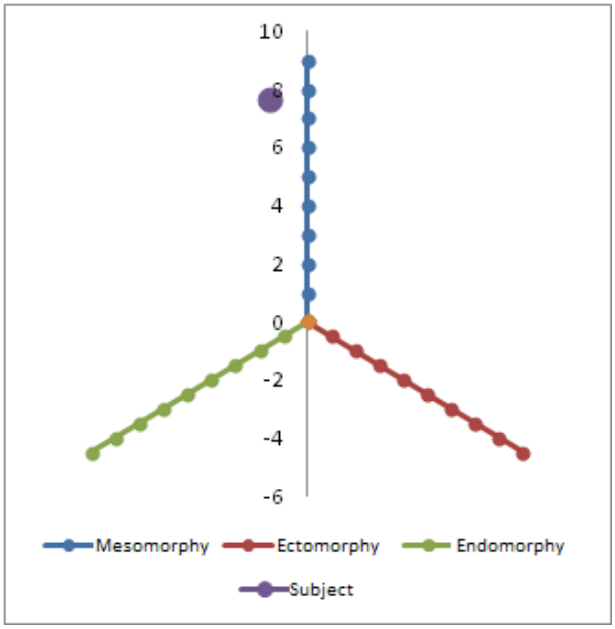


Fig. 9: Example of the somatograph of a subject

3.2 DEFINITION OF THE SWING MOVEMENT

The full golf swing using the driver club to strike the ball is a key element of success in golf. Therefore, in order to help enhance golfing performance it is important to identify the "performance determining factors" of the full golf swing [18].

The golf "swing" is a complex movement that involves the whole body. It transfers the energy of the movement to the ball through the club, directing the ball towards the objective. It requires coordination of muscles to develop the movement with the maximum efficacy.

Fig. 10: Swing parts

While many classification schemes have been used to describe the phases of the golf swing, this study divides the golf swing in seven essential parts:

1. Address
2. Early Backswing (Early BS)

3. Late Backswing (Late BS)
4. Initial Downswing (Initial DS)
5. Impact
6. Early Follow-through (Early FT)
7. Finish

1. Address (or set-up): the starting position for executing a golf swing should align the golfer properly with the target, establish dynamic and static balance, be in a sound biomechanical position (i.e. golf posture) and provide an effective grip of the club. (Fig. 11)

Fig. 11: Address

2. Early Backswing (Fig. 12a): it is the initial part of Backswing. During this phase, the club is held parallel to the ground. The purpose of Backswing is to position and align the golfer's hub centre and the club head so that the golfer can execute an accurate and powerful downswing. The Backswing is the movement of the golf club rearward, away from the ball, and then up and around the body, until the golfer reaches the point where he transfers the movement of the club forward again (the downswing). In a full golf swing, the Backswing will take the club up over the head, the golfer's shoulders turn over his hips and his hands reaching a position somewhere behind the right ear (for right-handed golfers).

3. Late Backswing (Fig. 12b): it is the final part of Backswing. During this phase, the hands of the golfer reach the final position, and then the movement of downswing starts.

c

Fig. 12: Early Back swing (Fig. 12a) and Late Back Swing (Fig. 12b)

4. Initial Downswing**:** "Downswing" is the term for that part of the golf swing that occurs between the end of the backswing and the impact with the golf ball. It starts from the Initial Downswing (Fig. 13), when the left arm still is prevailing and reaches the chin. Suddenly, the left arm descends downward, getting closer to the body and to the right hip, and then the weight completely changes to the left leg. The purpose of Downswing is to return the club head to the ball in the correct plane with maximum velocity.

Fig. 13: Initial Downswing

5. Impact: from the moment of the impact of the club head with the ball, the left arm ceases to act, while increases the action of the right arm and right hip. The right hip is rotated about 30 º to the target, while the club head stays behind the ball. (Fig. 14a)

6. Early Follow-through: the purpose of the follow-through is to decelerate the body and club head using the eccentric muscles action.

The club head is kept behind the ball, and the hands are crossed for the action of the left arm and the right hand, accompanied by the right shoulder and hip. (Fig. 14b)

7. Finish: at this point the hips are left to go until they result fitted to the target. The action is completed by the right shoulder and the right arm stretched and carried away to finish leaving on the same line of the left foot. (Fig. 14c)

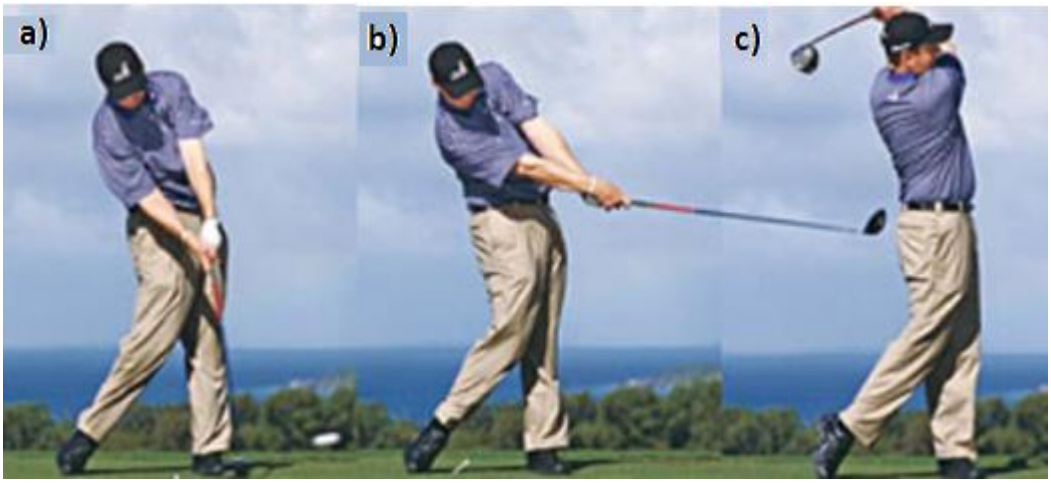


Fig. 14: Impact (Fig. 14a), follow-through (Fig. 14b) and finish (Fig. 14c)

3.3 INSTRUMENTATION

The biomechanical analysis of swing consists on the one hand, in a kinematic 3D motion analysis through a photogrammetric system; on the other hand, in studying the kinetic of movement with two dynamometric platforms (one for each foot).

3.3.1 Photogrammetric System - KINESCAN/IBV

In the current study, the system utilised for a 3D motion analysis was Kinescan/IBV 2011. This system is based on a video digital technology; it calculates the coordinates of the positions of different markers, providing information about positions of points, body segments or articulations, as well as kinetic and kinematic variables of the movements.
Kinescan/IBV allows a complete 3D analysis because of the characteristic of the system:

- Automatic processing of images
- Variable number of cameras, depending on the complexity of the model used to analyze the selected motion.

Fig. 15: Cameras of the Kinescan/IBV photogrammetric system

The photogrammetric system is composed of:

- Digital cameras - dimension: 80 mm (H), 81 mm (W), 67 mm (D); resolution: 832x832 píxeles
- Optics with IR filter (integrated into the cameras)

- Infrared spotlights with LED technology (integrated into the cameras)
- Cameras wiring
- PC for data processing
- Colour laser printer
- System of reflective markers (spherical, with diameters of 6, 12, 18 and 25 mm)
- Calibration system
- Related software

In the present study, the acquisitions were recorded with 10 cameras, at a sampling frequency of 250 frames per second (FPS).

The Kinescan/IBV software has the following characteristics:

- Managing data collected with the analysis
- Defining different analysis model for each study
- Setting capture parameters (number of cameras, frequency and maximum recording time)
- Displaying real time the measurement results in 3D, in order to verify the correct execution of gesture and analysis
- Setting parameters of interest and format of displayed graphs

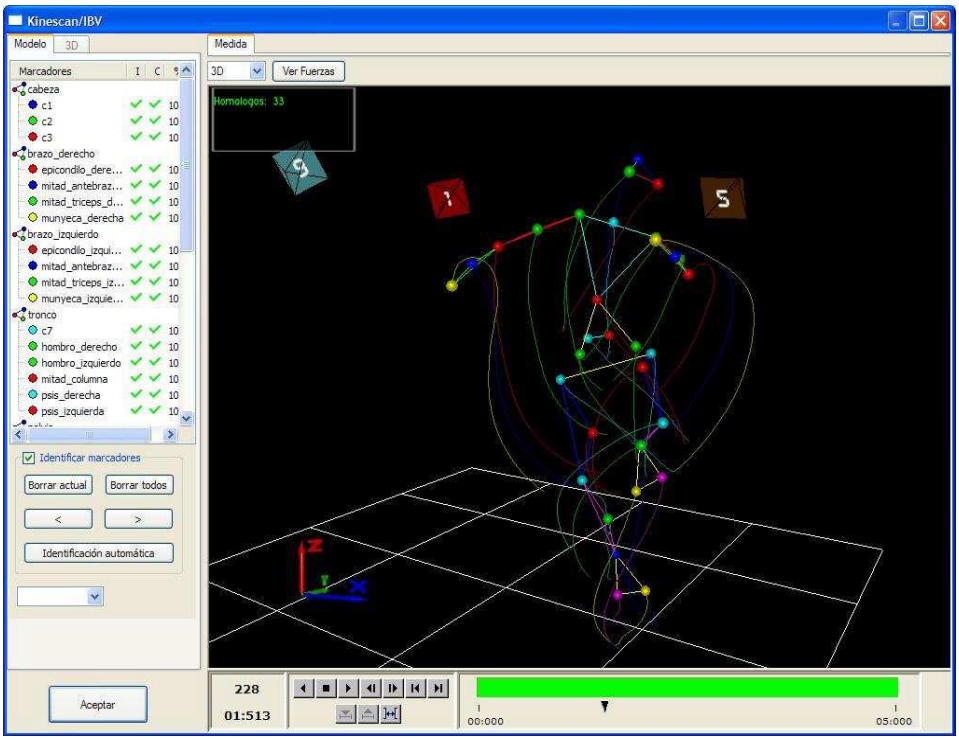


Fig. 16: Automatic digitalization of the system

3.3.2 Dynamometric Platforms – DINASCAN/IBV

The dynamometric platforms utilised in the present study, DINASCAN/IBV, have four extensometric articulated sensors, with characteristics of high linearity and sensitivity to low frequency. When a force acts on the dynamometric platform, the sensors generate electric signals proportional to the load they have in charge. Components of force reaction, torques and coordinates of the point of application of the resulting vertical force are calculated through equilibrium equations for every instant of time, according to the sampling frequency.

Every sensor is composed of eight extensometric gauges, four of them sensitive to vertical stress, and the other four to horizontal stress, with a Wheatstone bridge configuration.

The cross sensitivity between vertical and horizontal canals is avoided with an appropriate disposition, studied with finite element models.

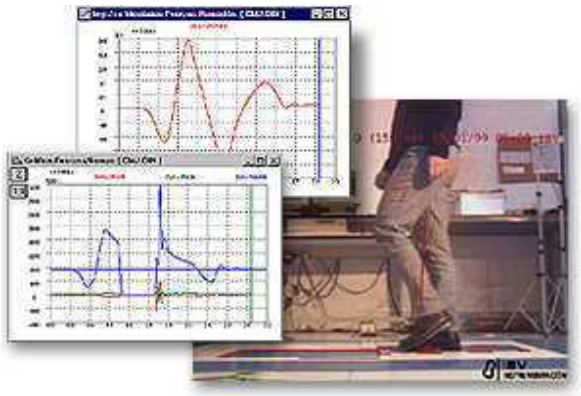


Fig. 17: graphics furnished by DINASCAN/IBV

Each platform has an internal amplification module to proportion high level analogical signals, which makes it exempt from electromagnetic perturbations.

Finally, the measure system is completed by a connection with the registration system, a data collecting card, a personal computer and the related software.

The sampling frequency used in this study was 250 Hz.

A representation of the laboratory set-up is reported in Fig. 18 :

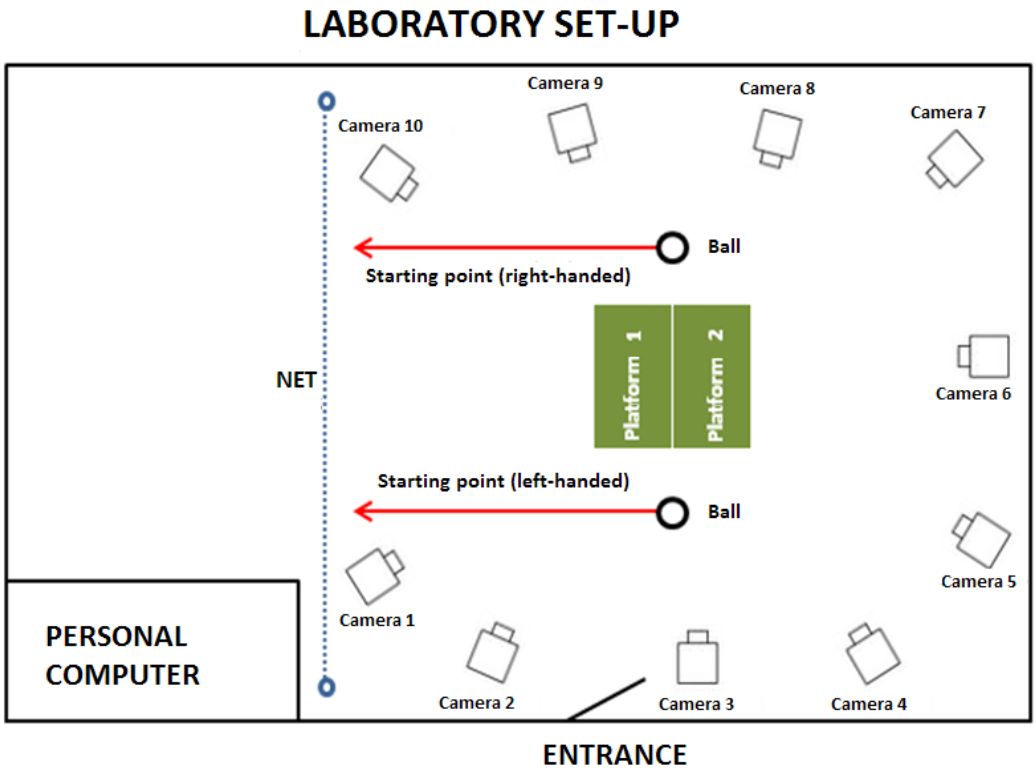


Fig. 18: Configuration of cameras and force platforms in the IBV laboratory during the golf swing analysis

3.3.3 3D Scanner

The 3D Scanner utilized for the present study was the VITUS Smart XXL Body Scanner. This instrument allowed 360 degrees imaging of the scanned person; it worked with 8 laser sensor heads, so it scanned the subject from front left, front right, back left and back right simultaneously.

The measuring time was approximately 12 seconds, and all the subjects were scanned without clothes, in a standard position (Fig. 19).

Fig. 19: 3D scanner measurement

The related software Anthroscan (Human Solutions) allowed the extraction of body measurements, calculated automatically by the software or determined by positioning markers.

3.3.4 Complementary Material

3.3.4.1 Plicometer

The thickness of skin folds of each golfer were measured through a plicometer. This instrument was substantially constituted by a clamp with a calibrated spring for applying a constant pressure on the skin fold of 10 g/mm². The measurements were given in millimeters by a mobile index of circular or linear scales.

Fig. 20: Plicometer

3.3.4.2 Segmometer

The osseus diameters were calculated with a segmometer. This instrument is made from a steel carpenter's tape which has attached two straight branches, each approximately 7 cm in length.

Fig. 21: Segmometer

3.3.4.3 Tape measure

Muscular perimeters were measured with a tape measure. It is a common measuring tool which consists in a flexible form of ruler, consisting of a ribbon of cloth, plastic, fiber glass, or metal strip with linear-measurement markings.

The measurements made with this instruments furnished additional information about the physical characteristics of the golfers. They were fundamental for the characterization of somatotype, which was made following the ISAK procedure [23], as reported in Par. 3.1.1.

3.4 EXPERIMENTAL PROTOCOL

3.4.1 Data collection protocol

This part of the study describes the complete procedure used to develop the analysis of the golf swing.

The investigation was composed of six different parts:

1. Reception of the golf player
2. Clinical Analysis
3. Anthropometric study
4. Markers implementation
5. Biomechanical Analysis of KKV (kinematic and kinetic variables) of swing
6. Data analysis

1. Reception of the golf player: the whole procedure and the characteristics of the equipment were explained to the players, before signing an authorization form.

2. Clinical Analysis: it was made by a physiotherapist and consisted of:

- a specific anamnesis of previous and present injuries of the patient;
- a musculoskeletal examination of all the different body segments;
- a postural analysis.

3. Anthropometric study: it consisted in a 3D analysis of the corporal characteristics of the subjects using the 3D-Scanner, plicometer, segmometer and tape measure. Anthropometric data collected through this instrumentation were elaborated, and all the corporal measures were obtained. After this, a definition of the somatotypes of the golfers was developed, according to the Heath-Carter protocol [6].

4. Markers implementation: The analysis makes use of 42 markers located in different anatomical position, as shown in Fig. 22:

Fig. 22: Positions of markers on a golfer

The biomechanical model was based both on the set of standards for reporting joint motion developed by ISB (International Society of Biomechanics), and on the CAST (Calibrated Anatomical System Technique) Protocol.

Among the 42 markers that compose the model, 38 are defined as technical markers, while the other 4 are calibration markers (that are used only during the calibration phase, to define the set of axes to describe the motion of the rest of the markers).

- 16 markers are sited on the lower extremities, divided into:

  Feet - 3 markers each foot, positioned on fifth metatarsal, cuboids, and calcaneus

  Legs - 2 markers each leg, positioned on internal and external malleolus

  Thighs - 3 markers each thigh, positioned on femoral internal and external condyles and on the trochanter
- 4 markers on the pelvis - positioned on the superior iliac spine, both internal and external
- 3 markers on the trunk - 1 marker on c7 and 2 markers on the left and right clavicular achromion
- 3 markers on the head - one on the forehead and two on the parietal lobes
- 12 markers on upper extremities:

  Upper-arms - 2 markers per upper-arm positioned on the radial and cubital apophyses

  Arms – 4 markers per arm positioned on the lateral biceps, on the triceps, on the epicondyle and epitroclea

- 3 markers on the club, on the club-head, and on the upper and lower part of the bar
- 1 reflecting circular marker to compose the ball

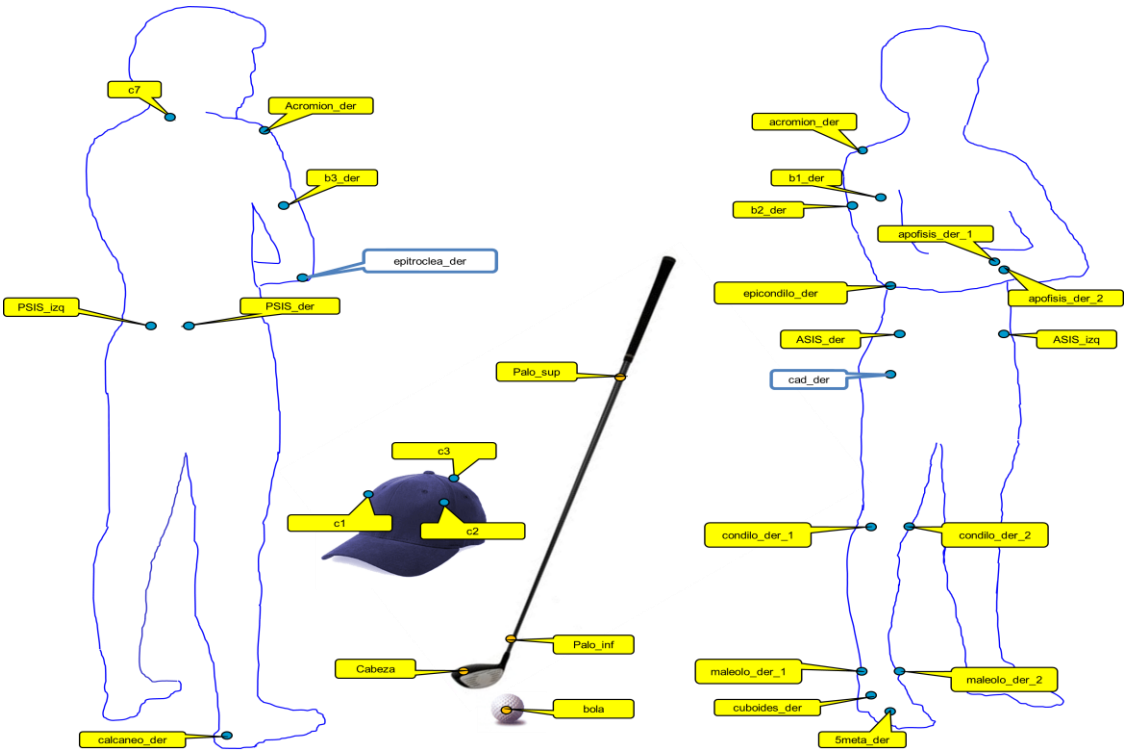


Fig. 23: Model of markers – calibration markers are coloured in blue, technical markers in yellow

5. Biomechanical Analysis of KKV of swing: this analysis has been conducted using the photogrammetric system KINESCAN/IBV, synchronized with the dynamometric system DINASCAN/IBV for a real-time recording of the KKV of golf swing. The different steps for recording KKV were:

a) Swing warm-up: the subjects were instructed to hit the ball from 3 to 5 times to warm up. This phase was not registered.

b) Calibration, realized with a "T" posture. The time of recording was less than 1 second, to let the golfer maintain a static position. Calibration allows obtaining the positions of calibration markers relatively to technical markers during the swing measures. Moreover, it gives the chance of initializing articular angles, since articulations are forced to assume a neutral angle during the calibration posture. The posture described is:

- Parallel feet on the same line of shoulders
- Knees extended

- Erect trunk
- Shoulder extended 90º degrees on the frontal plane, forming a "T" with trunk and lower extremities
- Elbows extended
- Supin upper-arms
- Head looking ahead

c) Data collection: each subject made 5 swing tests, using the same driver club. For each test a complete movement of swing was recorded. The golfers started the swing after 3 seconds from the measurement start, following a vocal input. This allowed having also information about the set-up posture.

The driver club used was the same for all the subjects. The driver club was projected according to the physical characteristics of all the subjects.

The recording of gesture was made in 3-dimensions, but also with a 2D complementary camera to keep stored the real data.

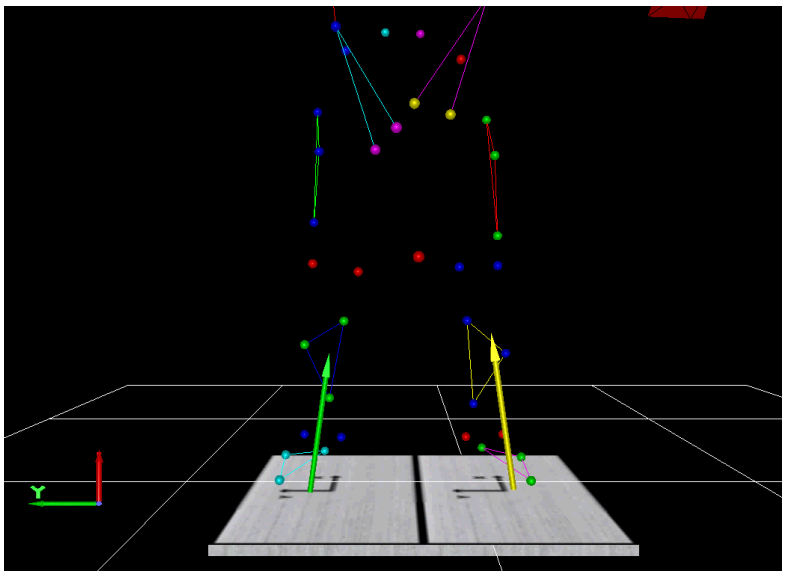


Fig. 24: Digitalizing Screen of Biomechanical Analysis of swing

During the analysis of KKV, an artificial grass was used in order to improve the similarity of the external conditions with a golf course, and a net was positioned in front of the players to hit the ball.

Fig. 25: Laboratory set up: artificial grass on the dynamometric platform

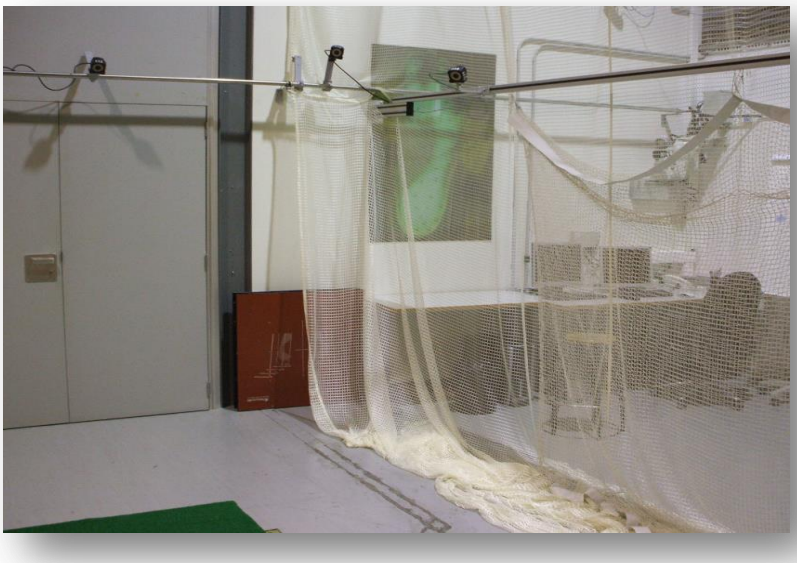


Fig. 26: Laboratory set up: the net

6. Data analysis: the analysis of all the variables of interest and of the statistical analysis developed is presented in par. 2.5.

3.4.2 Biomechanical Model

After cameras recording images, several steps are required to obtain the quantities useful to describe the kinematics of the various limbs:

1) Acquisition of the markers time-varying spatial coordinates
2) Smoothing and processing of stored signals
3) Computation of angular and linear velocities
4) Computation of displacements

1. Acquisition of markers coordinates: to determine the spatial coordinates of a marker, starting from the digital camera recording, at least two synchronized cameras are needed. Each camera projects the marker position on its own flat sensor. An algorithm is then necessary to reconstruct spatial 3D coordinates from the planar ones. This algorithm is the DLT (Direct Linear Transformation) [3] whose base relationships are the following:

$$u = \frac{L_1 X + L_2 Y + L_3 Z + L_4}{L_9 X + L_{10} Y + L_{11} Z + 1}; v = \frac{L_5 X + L_6 Y + L_7 Z + L_8}{L_9 X + L_{10} Y + L_{11} Z + 1}$$

where (u v) are the coordinates of the marker on the sensor plane and (X,Y,Z) are the spatial coordinates with respect to a chosen reference axis system, L_1 to L_{11} are coefficients intrinsic to the camera, dependent on its characteristics, that can be determined with a preliminary calibration. For each marker, the number of the unknown coordinates is three, whereas the number of known quantities is two. So a number of cameras ≥ 2 is necessary and the method of least squares furnishes the best approximation to the solution.

2. Processing of stored signals: spatial coordinates are time-varying signals (X(t), Y(t), Z(t)). The acquisition frequency must match the body movement rapidity. In this case the acquisition frequency of 250 Hz was estimated sufficient to follow the golfer body movement. A smoothing procedure is necessary to obtain analytical functions that can be differentiated or integrated. In this case the algorithm includes a cubic local regression based on a third degree polynomial function.

3. Computation of angular and linear velocities: for solving the velocity problem, a method based on a mechanical analogy is used, relating linear and angular momentum to linear and angular velocities, respectively.

At the time t the generic marker denoted by P_i, belonging to the rigid body S, has coordinates (X_i,Y_i,,Z_i) which form the components of a vector $\mathbf{R}_i$ (see the figure below).

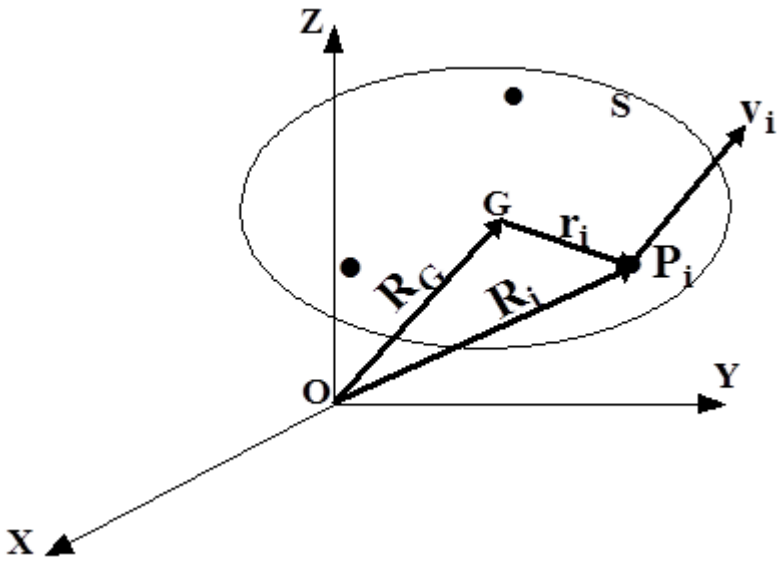


Fig. 27: Representation of vectors for description of body instantaneous motion

In the same representation, G is the centroid of the cluster set, and $\mathbf{r}_i$ is the relative vector

$$R_G = \frac{1}{n}\sum R_i ; r_i = R_i - R_G$$

(summation is extended over n points)

For a rigid body there is a single relationship between the velocities of the centroid G and any point P arbitrarily chosen, in particular any marker P_i

$\mathbf{v}_i = \mathbf{v}_G + \mathbf{w} \times \mathbf{r}_i$ (× means vectorial product)

w is the body angular velocity. The instantaneous screw axis or helical axis (ISA) is a characteristic of the rigid body. It is the axis around which the rigid body rotates and along which it moves. Its direction is parallel to **w** and its position is defined by

$\mathbf{r}_G = \mathbf{w} \times \mathbf{v}_G / w^2$

Summarizing, the instantaneous motion of the body can be completely described by these two vectors: the angular velocity **w** and the centroid velocity $\mathbf{v}_G$. From these vectors it is possible to compute the velocity of any point as well as the location of the ISA.

The calculation of $\mathbf{v}_G$ from the measured marker velocities $\mathbf{v}_i$ is obvious

$$v_G = \frac{1}{n}\sum v_i$$

The angular velocity can be determined by means of a simple analogy. Considering the markers as point of unitary mass ($m_i = 1$) that define together a fictitious rigid body, then its movement causes an angular momentum, $\mathbf{L}_G$ which can be computed as

$$\mathbf{L}_G = \sum_i m_i \mathbf{r}_i \times \mathbf{v}_i = \bar{\bar{\mathbf{J}}}_G \mathbf{w}$$

where $\overline{\overline{J_G}}$ is the inertia tensor of the markers system calculated at G and given by

$$\bar{\bar{\mathbf{J}}}_G = \begin{bmatrix} \sum (y_i^2 + z_i^2) & -\sum x_i y_i & -\sum x_i z_i \\ -\sum x_i y_i & \sum (x_i^2 + z_i^2) & -\sum y_i z_i \\ -\sum x_i z_i & -\sum y_i z_i & \sum (x_i^2 + y_i^2) \end{bmatrix}$$

(x_i, y_i, z_i) being the components of the vector $\mathbf{r}_i$. Thus, a direct closed-form expression for the calculation of **w** can be obtained as follows:

$$\mathbf{w} = \bar{\bar{\mathbf{J}}}_G^{-1} \sum \mathbf{r}_i \times \mathbf{v}_i$$

In the ideal case of no error in the measurements, only three markers are enough to exactly calculate **w**, but in the real case where errors are normally present, it is better to base this calculation on more than three points and the method of least squares is then used to get the best approximation to the solution.

4. Computation of displacements: instead of starting with the finite displacement analysis, and then obtaining the kinematic variables by differentiation, the algorithm uses the results of the velocity analysis to simplify the determination of finite displacements. The procedure is entirely described in [37] and we omit it here for brevity.

3.4.2.1 Definition of Anatomical Axes

For each joint studied, a coordinate system was realised in order to define all the articular angles, angular velocities and torques. They are represented below.

1. Ankle Coordinate System

o: the origin coincident with the midpoint between the two malleolus.

x: the line connecting the two malleolus.

z: the line perpendicular to the x-axis, joining the origin and the midpoint between the two condyles (a rectification was needed in order to make the axes perpendiculars).

y: the line perpendicular to both y- and z-axis, pointing anteriorly.

Fig. 28: Ankle coordinate system

2. Knee Coordinate System

o: the origin coincident with the midpoint between the two condyles.

x: the line connecting the two condyles (a rectification was needed in order to make the axis perpendicular to the frontal plane).

z: the line perpendicular to the x-axis, joining the origin and the trochanter.

y: the line perpendicular to both y- and z-axis, pointing in walking direction.

3. Hip Coordinate System

o: the origin coincident with the trochanter

x: the line connecting the two trochanters of left and right legs

z: the line perpendicular to the x-axis, pointing cranially

y: the line perpendicular to both y- and z-axis, pointing in walking direction

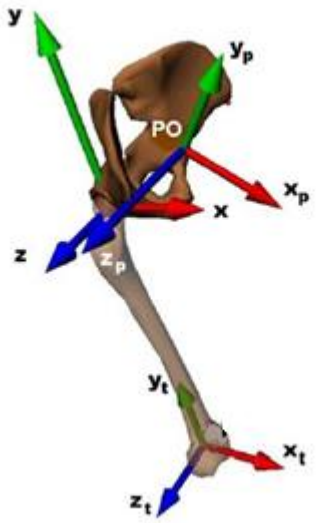


Fig. 29: Hip and knee coordinate systems

4. Pelvic Coordinate System

o: the midpoint of the plane passing through the four iliac spine points.

x: the line that lies in the pelvic transverse plane and, which is perpendicular to the z-axis and its positive direction is anterior.

z: the line passing through the two external iliac spines with its positive direction pointing right.

y: the line perpendicular to both the x-axis and the z-axis, pointing anteriorly.

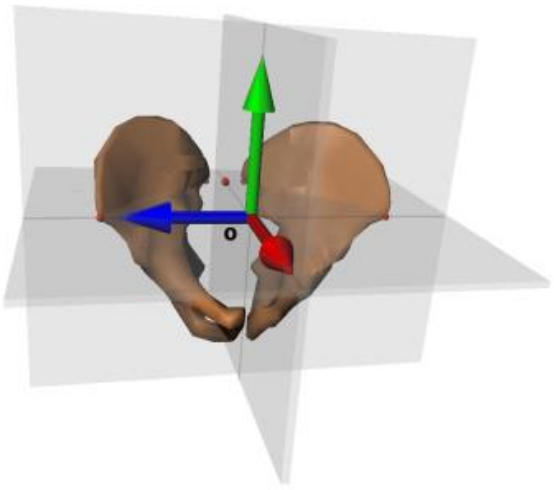


Fig. 30: Pelvic coordinate system

5. Trunk Coordinate System

o: the origin coincident with the c7.

x: the line connecting the two achromions.

z: the line perpendicular to the x-axis, joining c7 and the midpoint between the trochanters.

y: the line perpendicular to both y- and z-axis, joining the achromion and the epicondyle.

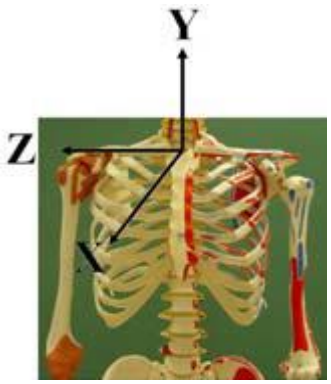


Fig. 31: Trunk coordinate system

6. Arm Coordinate System

o: the origin coincident with the clavicular achromion.

x: the line joining the clavicular achromion and the epicondyle

connecting the two achromions.

z: the line perpendicular to the x-axis, pointing upwards.

y: the line perpendicular to both y- and z-axis, pointing anteriorly.

7. Elbow Coordinate System

o: the origin coincident with the epicondyle.

x: the line joining the clavicular achromion and the midpoint between the radial and the cubital apophises.

z: the line perpendicular to the x-axis.

y: the line perpendicular to both y- and z-axis, pointing anteriorly.

8. Wrist Coordinate System

o: the origin coincident with the midpoint between the radial and the cubital apophises.

x: the line joining the origin and the first point of the club bar.

z: the line perpendicular to the x-axis, pointing upwards.

y: the line perpendicular to both y- and z-axis, pointing anteriorly.

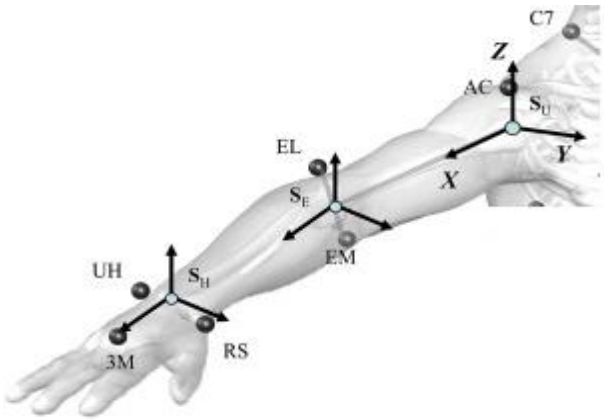


Fig. 32: Arm, elbow and wrist coordinate systems

3.4.2.2 Definition of Anatomical Planes

For each joint system, the frontal plane is defined as the normal plane to the y-axis, while the sagittal plane is normal to the x-axis, and the transversal plane is normal to the z-axis.

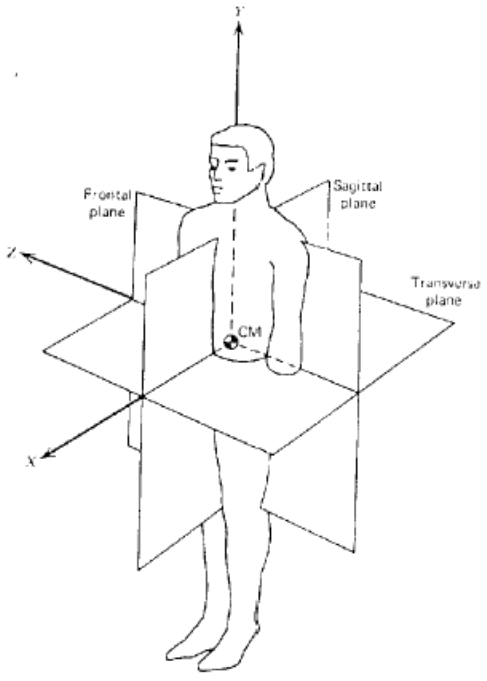


Fig. 33: Standard anatomical planes

To study the golf swing, different movements were investigated, which were considered the most significant for the analysis gesture:

1. Flexion-extension: the act of stretching or straightening out a flexed limb on the frontal plane. Flexion is the act of bending a joint or limb in the body by the action of flexors. The extension of a joint is moving toward its most straight position.
2. Adduction-abduction: the act executed on the sagittal plane of bringing a part of the anatomy closer to the middle sagittal plane of the body (adduction) and of drawing a limb away from the median sagittal plane of the body (abduction).
3. External-internal rotation: the act executed on the transverse plane of turning outwardly or away from the midline of the body (external rotation) and of rotating towards the center of the body (internal rotation). The external rotation can also be defined as lateral rotation: in this case, right rotation and left rotation are distinguished.
4. Lateral inclination: the degree of deviation from a particular plane, on the right or the left side.
5. Supination-pronation: the act of turning the palm forward or upward, or of raising the medial margin of the foot (supination) and to turn or rotate a limb so that the inner surface faces down or back (pronation).
6. Ulnar-radial deviation: physiological movement of the wrist, where the hand including the fingers move towards the ulna (ulnar deviation), and where wrist is bent toward the thumb (radial deviation).

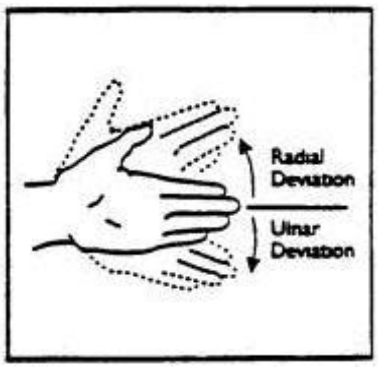


Fig. 34: Representation of radial and ulnar deviation

3.5 DATA PROCESSING

3.5.1 Parameters of Analysis

In the present study, three types of parameters were analyzed:

1. Biomechanical variables:

- Joint angles (angles described by ankles, knees, hips, pelvis, trunk, head, shoulders, elbows and hands in the different anatomical planes)
- X factor (divided into: X factor_top, measured at the top position of backswing, X factor_strech rel, measured at the moment that a relative rotation starts of pelvis just after the top position, and X factor_mid impact, measured at the moment of impact)
- Joint Angular Velocities
- Articular Torques (only for the lower extremities): x, y and z components
- Time (duration of the whole swing, duration of the backswing phase and duration of the downswing)
- Ground ReactionForces (GRF): x, y and z components
- Ground Reaction Torques
- Centre of Pressure (COP) displacements: antero-posterior and medio-lateral displacement

2. Performing factors:

- Club Head Speed At Impact
- Horizontal Launch Angle
- Handicap

3. Anthropometrical and kinanthropometrical parameters:

- Height, length, width and diameters of all the body segments of interest
- Endomorphy, mesomorphy and ectomorphy

3.5.2 Statistical Analysis

The program R version 2.15.0 (2012-03-30) was used for data analysis. The statistical study developed was mainly divided into two parts:

1. Descriptive analysis
2. Correlations with performing parameters

The descriptive analysis of the sample was developed calculating, for each variable:

- Mean value
- Standard Deviation
- Minimum value
- Maximum value

Correlations were studied between:

- anthropometrical and somatotype parameters and biomechanical variables
- biomechanical variables and golf performing factors
- anthropometrical and somatotype parameters with golf performing factors

Pearson correlation coefficient (correlation index) and p-value were calculated to detect significant correlations. Correlations were considered significant when presenting a correlation index of approximately 0.5 or above, and a p-value ≤ 0.01.

4. RESULTS

4.1 DESCRIPTIVE ANALYSES

4.1.1 Descriptive analysis of the biomechanical parameters of the swing.

For each joint system, the descriptive analysis of the following kinematic parameters was developed:

- angles
- angular velocity
- torques (only for the lower extremities' joint systems)
- X factor

Moreover, a descriptive analysis of the following kinetic parameters was carried out:

- Time
- Ground Reaction Forces
- Ground Reaction Torques
- COP displacements

The mean values, standard deviation, minimum and maximum values of all the variables studied are reported in Appendix I.

In this part, the trends during the swing motion of all the parameters reported above are described.

4.1.1.1 Ankle

In this joint system, it can be noticed an increase of extension at the moment of impact (the mean values report a variation from an angle of flexion of 4,64º during the address phase to an angle of extension of -14,34º at the impact, for the right ankle, and a variation from 1.54º to -14.7º for the left one). Moreover, the results evidence that the ankle joint remains abducted during the whole movement of swing, with maximum values measured of 24º and 25º respectively for the right and the left part at the impact. Regarding the

external/internal rotation of this joint, different trends are shown for the two ankles: the right one is extra-rotated at the address, then intra-rotates during the phases of the backswing and downswing, and finally extra-rotates from the moment of the impact to the finish; the left one starts doing the opposite during the different phases. The angular velocity results maximum at the moment of impact, with a mean value of 240.4º/s for the right ankle and 187.4º/s for the left side. The articular torques basically show bigger values of the X-components compared to the Y and Z.

4.1.1.2 Knee

On the frontal plane, the knees remain flexed for the whole movement of swing. Moreover, the right knee is found to be extra-rotated for the most part of the gesture, with the exception of the moment of impact and early FT. The left knee, instead, shows an extra-rotation also at impact, while is intra-rotated in the phase of late BS and initial DS. The angular velocity of this joint, as well as the ankle's velocity, is maximum at the impact, with mean values of 267.2º/s and 199.3º/s respectively for the right and left leg. The three components of the torque of the right knee increase during the impact and the early FT phases, while for the left knee the maximum mean values of the torques are shown at the initial DS.

4.1.1.3 Hip

The hip, on the frontal plane, tends to be flexed for most of the swing parts. Nevertheless, the right hip extended during the last two phases of the swing (early FT and finish), with a maximum mean angle reported of 16.97º at finish. Also the angular velocity of the hip, as for the rest of the leg's joints, is maximum at the moment of impact, with mean values of 417.9º/s and 348.0º/s for the right and the left side. The components of the articular torques assume predominantly negative values at the beginning of the movement (with the exception of the Y-component of the right hip, which has a positive mean value). No significant variations are reported between the different components during the different parts of swing.

4.1.1.4 Pelvis

The pelvis starts the swing movement with an average angle of flexion around 20º. After the initial DS, though, the flexion tends to decrease, and during the early FT is reached the maximum angle of extension observed, 17.4º. Laterally, this joint system presents a right flexion for almost the whole movement, with a left mean flexion of 0.2º during the address and of 14.11º at finish. On the transverse plane, it can be noticed a little left rotation at the address, followed by an increasing right rotation during the early BS, late BS and initial DS (respectively from 29.77º to 52.41º). Then, the rotation is inverted and the movement ends with the pelvis rotated on the left (116.8º at finish). Once more, the angular velocity is maximum at impact, with a mean value reported of 322.5º/s.

Starting from this joint system, it was not possible to calculate the articular torques with the biomechanics of rigid bodies. Thus, the torques generated in the joint systems of the upper extremities are not reported in these results.

4.1.1.5 Trunk

The trunk mainly remains flexed for the entire swing. The only mean extension angle reported is 17.81º at finish. The lateral inclination changes from the right (address) to the left (until the initial DS), and then returns to the right for the last phases. The rotation, instead, is predominantly on the right (with a maximum mean value of -56.27º at the initial DS), making en exception for the moments of address and finish, when the trunk rotates to the left (with an angle of 49.32º). The maximum angular velocity is reached at the early FT: it can be noticed that the mean value continues increasing after the impact (the maximum mean velocity reported is 470.8º/s compared with 239.18º/s when the club impacts the ball).

4.1.1.6 Head

The position of the head in the frontal plane is mainly extended. The greater values are found at impact and early FT, with 24.68º and 30.48º. In addition, it is generally inclined on the right at the beginning of the movement, and then inclines on the left starting from the impact. The lateral rotation seems to show an opposite trend, with a left rotation during the first parts of the movement (excepted to the address position) and a right rotation at the

end of the swing. The head angular velocity, again, is maximum at the moment of impact, although it never reaches great values (the maximum result is 13.81º/s).

4.1.1.7 Shoulders

On the frontal plane, the right shoulder shows an angle of flexion during the whole movement of swing, while the left shoulder is extended for the entire gesture. Both of the shoulders are pronated in all the phases, even though a difference is reported at finish, when the right part reaches its maximum mean value (127.3º) and the left part reaches its minimum (21.06º). The angular velocity is maximum at early FT for the right shoulder (227.9º/s) and at impact for the left one (151.2º/s).

4.1.1.8 Elbows

The right elbow seems to remain mainly flexed during the swing. The left elbow, instead, shows an alternation of flexion and extension during the different phases (starting extended at address and finishing flexed). Moreover, the right elbow is pronated from the beginning of the swing until the impact, and then supinates in the early FT and finish phases. The left elbow, instead, is supinated for the whole movement excepted during the early FT, when the mean angle reported is 31.98º of pronation. The left elbow shows the maximum value of the mean angular velocity at the moment of impact, with a value of 1052.6º/s.

4.1.1.9 Hands

The trend of flexion/extension of the two hands on the frontal plane is opposite in the results, it is shown that the right hand is extended for almost the whole movement, while the left one is predominantly flexed. To study the movement of the hands during the swing, the angle of radial and ulnar deviation were also calculated. The main deviation seems to be radial for both the hands, although they have a ulnar deviation at finish (respectively of 18.6º and 7.28º), and the left hand also has a mean angle of ulnar deviation at initial DS (33.5º). The mean angular velocity is maximum during the phases of impact and early FT (it is attested to be respectively around 1600-950º/s for the right hand and 1150-1170º/s for the left one).

4.1.1.10 X factor

The X factor maximum mean value is shown at the top of backswing (61.5°). X factor relative stretch, instead, has a low mean value (4.5°) compared with the other two components (the X factor at mid impact is reported as 30.1°).

4.1.1.11 Time

The time of the complete swing reported is 1.632 s (mean value, with a minimum value of 1.32 s and a maximum of 2.3 s), with the 0.8 s reported for the backswing and the 0.27 s of the downswing.

4.1.1.12 Ground Reaction Forces

Among the three components of the GRF, the Z-component has the bigger values for both the right and the left side. This component shows a decrement (from 380 N to 194 N) during the swing (with the maximum mean value of 611.2 N reported at early BS), while the left GRF increases from 383 N to 539.2 N from address to finish.

4.1.1.13 Ground Reaction Torques

The GR Torques show their maximum mean values at late BS and initial DS (12.6). At finish, instead, the maximum negative value is reached (-12.4). The trend of these torques generated by the GRF during the swing motion is represented in Fig. 35. It can be noticed that at the beginning of the swing the right foot generates the biggest GR Torque that increases at the beginning of the backswing, and then decreases after the top of the backswing. After the impact it remains null until the end. The GR Torque of the left foot, instead, increases after the top of back swing reaching its maximum during the follow through.

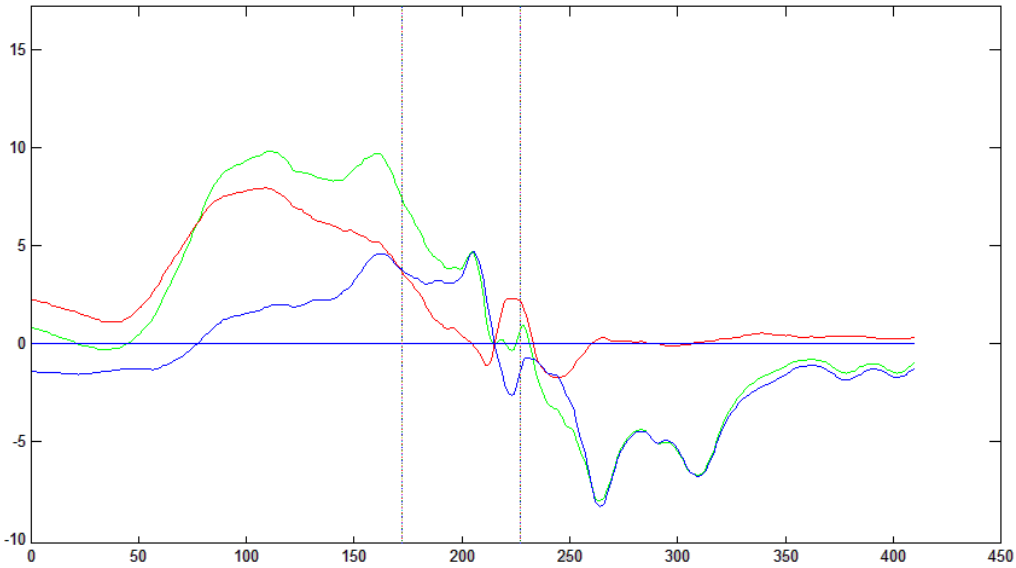


Fig. 35: Representation of the trend of GR Torques during the different phases of swing. The green line represents represents the GR Torque of the Right foot, the blue line the GR Torque of the Left foot, and the red line is the result of the torques of the two feet. The first vertical line indicates the moment of the top of backswing, while the second one is at the moment of impact.

4.1.1.14 COP displacement

The medio-lateral and antero-posterior displacements of COP do not have huge variation during the execution of swing: the mean values show an excursion between 0.332 and 0.419 for the X-component and from 0.286 and 0.549 for the Y-component.

4.1.2 Descriptive analysis of the anthropometrical parameters of the swing.

A descriptive analysis of the sample was carried out. Mean value (MEAN), Standard Deviation (STD), Minimum value (MIN)and Maximum value (MAX) were calculated for each parameter collected, as specified in the statistical analysis description.

In Table 5 is reported the analysis of three fundamental anthropometrical parameters: age, body mass and height of the subjects. All the other anthropometrical variables examined are reported in Appendix II.

	MEAN	STD	MIN	MAX
Age _years	21.50	1.98	17.00	23.00
Body_ mass_kg	80.02	13.74	57.40	107.50
Body_height_cm	176.81	8.21	165.10	190.00

Table 5: Mean, Standard Deviation, Minimum and Maximum values of age, body mass and height of the sample.

In Table 6 are reported the values represented in Fig. 36:

	MEAN	STD	MIN	MAX
Endomorphy	3.75	1.195	2.20	5.80
Mesomorphy	4.40	0.551	3.50	5.30
Ectomorphy	2.22	1.109	0.10	3.30

Table 6: Mean, Standard Deviation, Minimum and Maximum values of somatotype's parameters.

Fig. 36 shows a diagram that represents the descriptive analysis of the somatotype assessment.

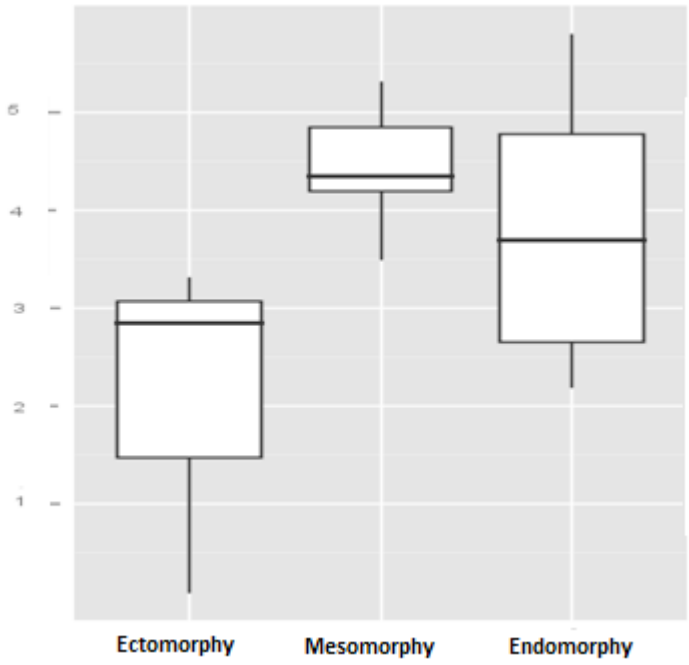


Fig. 36: Diagram of the somatotypes examined

To scale the results found, the values of somatotype reported can be compared with the reference mean values of somatotype, which are 2.3 – 4.6 – 2.8 respectively for endomorphy, mesomorphy and ectomorphy [26]. Comparing these results with other

findings, the values found (3.75 – 4.40 – 2.22 respectively for endomorphy, mesomorphy and ectomorphy) showed that the golfers examined for this study are more endomorph than turquish [22] and less than argentinian golfers [26] (endomorphy = 2.8 and 4.5 respectively). Argentinan players showed also the highest mesomorphy (5.1 compared with 4.4 and 4.5 of these subjects and the turquish ones) while the turquishes presented the highest value of ectomorphy (3) compared with the other two (2.22 and 2.1 respectively).

In Appendix II all the results of the somatotype study of the players are reported.

4.1.3 Descriptive analysis of the performance parameters of the study sample

Ball flight distance and direction of flight are normally chosen as indexes to evaluate the performance of a shot. They are determined by the release velocity and spin rate of the ball after impact, as well as by the air conditions. In turn the ball velocity and spin rate directly depend on momentum and angular momentum of the club head at the moment of impact [5]. Therefore, club head speed at impact, as well as horizontal launch angle can be assumed as indicators in assessing performance. Moreover handicap reflects the golfer ability reached gradually, lower handicap corresponding to better golfer. The following parameters, shown in Table 7 were taken as performing factors of the present study.

	MEAN	STD	MIN	MAX
Club Head Speed at Impact (km/h)	161.56	8.99	145.958	181.61
Horizontal Launch Angle (°)	4.26	3.23	0.209	14.00
Handicap	3.67	1.53	- 1.7	5

Table 7: Descriptive Analysis of the performance parameters of the golf swing

The correlation between these factors and the anthropometrical and biomechanical parameters were taken as a measure of performance of the golf swing.

4.2 CORRELATIONS

In this part, the correlations existing between the different types of variables studied are analyzed through the statistical study explained in paragraph 3.5.2. Correlations, as already specified, were considered significant when presenting a correlation index ≥ 0.45 and a p-value ≤ 0.01.

In Appendix III, the values of correlation index and p-value are reported for all the correlations examined. The variables that showed a p-value ≤ 0.01 with the performing factors are reported in red. The variables that presented an absolute value of the correlation index around 0.5 or more are reported in green.

In the following paragraphs, during the analysis of influence of the various data, some significant examples are reported, some of them illustrated by the corresponding graphs.

Being the number of combinations very high, some selective criteria for presentation were necessary:

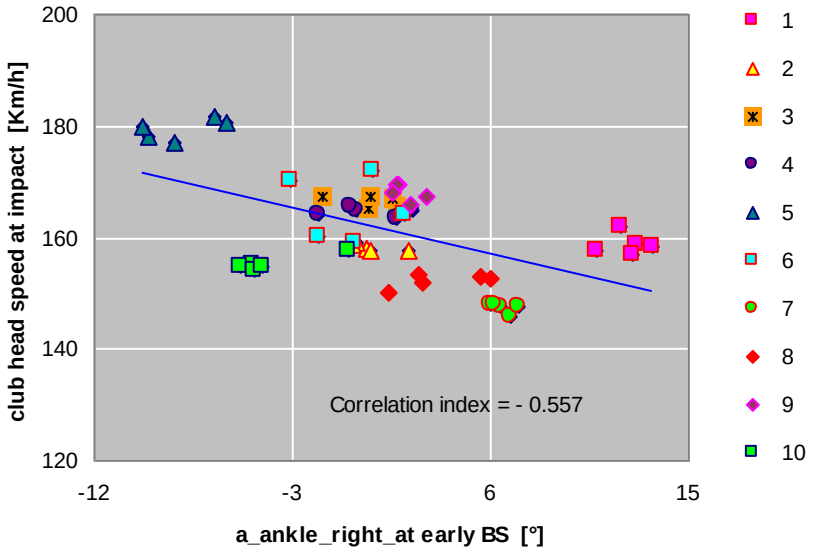
- Some summary tables were prepared with the aim of simplifying the interpretation and analysis of the great amount of available data reported in Appendix III. In the summary tables, only cases corresponding to linear correlation index ≥ 0.45 were chosen and indicated by a proper symbol. The condition $p < 0.001$ was always verified and it is not mentioned in the Tables. In this way, a synthetic view is attainable and several considerations may be drawn.
- Only graphs with linear correlation index absolute value ≥ 0.55 and p-value ≤ 0.001 were represented.

4.2.1 Analysis of the influence of the biomechanical variables on the golf performing factors

One of the main purpose of this work was to point out meaningful correlations between biomechanical variables and performing factors. Among the available performing factors, Club Head Speed at impact (CHS), horizontal ball launch angle (HLA) and Handicap (H) were chosen to represent swing effectiveness. Significant correlations were obtained for:

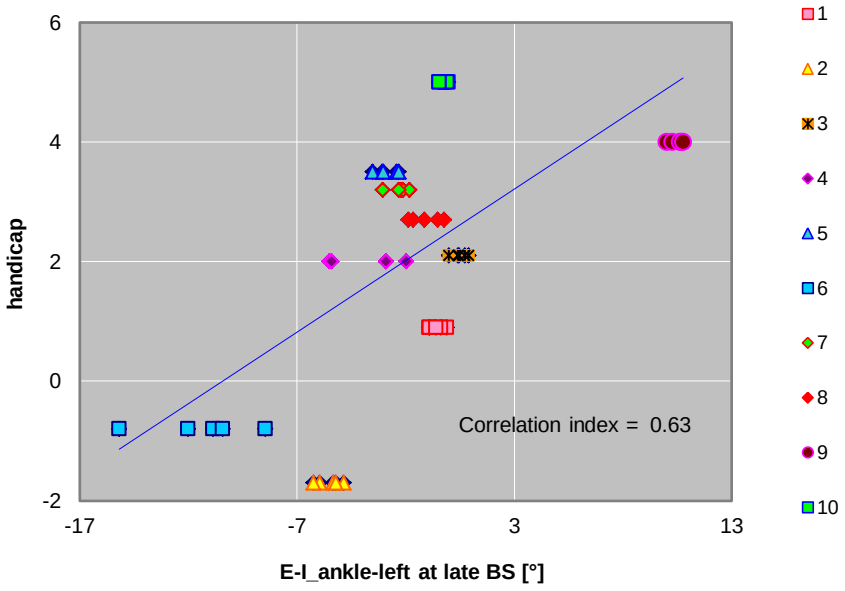
3.2.1.1 Ankle

Right Ankle Angle: between the angle of abduction-adduction and CHS at address, early BS and late BS; between abduction-adduction and HLA at early FT.



Graph. 1: Correlation trend between CHS and Right Ankle Abduction-Adduction at early BS for the different golfers.

Left Ankle Angle: between abduction-adduction and H at impact and early FT; between external-internal rotation and H at address, early BS, late BS, initial DS and finish.



Graph. 2: Correlation trend between H and Left Ankle External-Internal Rotation at late BS for the different golfers.

Ankle Angular Velocity: with HLA at impact, for the right side.

Right Ankle Torque: at address, between X, Y, Z components and CHS, HLA; at impact and early FT between X component and H.

Left Ankle Torque: at late BS, between the three components and H; at impact, only X component was correlated with H, while Z component with HLA; at initial DS, between Y component and HLA.

Right Ankle Table

	ANGLE									TORQUE									ANG. VEL.		
	F-E			AB-AD			E-I			X			Y			Z					
	CHS	HLA	H	CHS	LA	H	CHS	HLA	H	CHS	LA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS				O						X	X		O			X	O				
EARLY BS				O																	
LATE BS				O																	
INITIAL DS																					
IMPACT												O								O	
EARLY FT												O									
FINISH					O																

Table 8: Significant correlations between Right Ankle (Angle, Torques and Angular Velocity) and Performing Factors

O = 0.45 ≤ abs(correlation index) ≤ 0.6 X = 0.6 ≤ abs(correlation index) ≤0.7 Y = 0.7 ≤ abs(correlation index)

Left Ankle Table

	ANGLE									TORQUE									ANG. VEL.		
	F-E			AB-AD			E-I			X			Y			Z					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS									O												
EARLY BS									X												
LATE BS									X			O			O			O			
INITIAL DS									O					O							
IMPACT												O					O				
EARLY FT						O															
FINISH						O			O												

Table 9: Significant correlations between Left Ankle (Angle, Torques and Angular Velocity) and Performing Factors

3.2.1.2 Knee

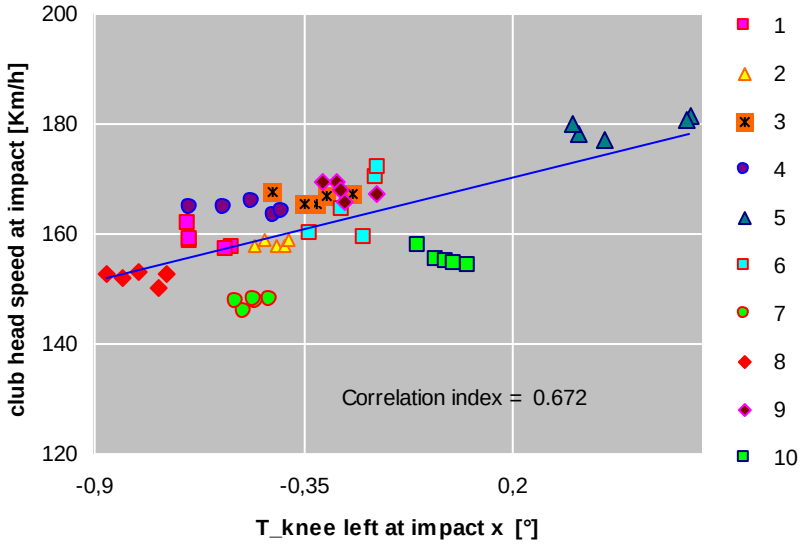
Right Knee Angle: between the angle of flexion-extension and H at address; between adduction-abduction and H at initial DS.

Left Knee Angles: between flexion-extension and H at address.

Knee Angular Velocity: for the right side, with CHS and HLA (particularly significant value of correlation: 0.660 with p-value of 0.001) at impact; for the left side, with CHS at finish, and with HLA at late BS.

Right Knee Torque: for X component, with HLA at early BS; for Y component, with CHS at late BS; for Z component, with CHS at impact and early FT.

Left Knee Torque: for X component, with CHS at impact, with HLA at initial DS and impact, and with H at late BS; for Y and Z component, with CHS and HLA at impact (particularly significant value of correlation for Z component: -0.775 with p-value < 0.001).



Graph. 3: Correlation trend between CHS and Left Knee Torque at impact for the different golfers.

Right Knee Table

	ANGLE									TORQUE						ANG. VEL.		
	F-E			E-I			X			Y			Z					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS			O						O									
EARLY BS								O										
LATE BS										O								
INITIAL DS						O												
IMPACT													X			O	X	
EARLY FT													O					
FINISH	Y	X																

Table 10: Significant correlations between Right Knee (Angle, Torques and Angular Velocity) and Performing Factors

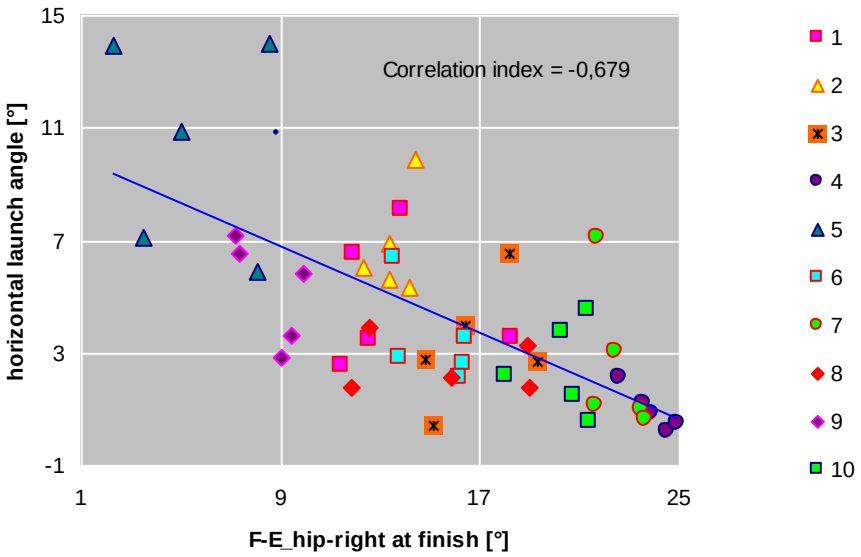
Left Knee Table

	ANGLE						TORQUE									ANG. VEL.		
	F-E			E-I			X			Y			Z					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS			O															
EARLY BS																	O	
LATE BS									O									
INITIAL DS								O										
IMPACT		O					X	O		O	O		Y	O				
EARLY FT																		
FINISH				Y												O		

Table 11: Significant correlations between Left Knee (Angle, Torques and Angular Velocity) and Performing Factors

3.2.1.3 Hip

Right Hip Angle: between the angle of flexion-extension and CHS during the all swing except for the late BS (when the correlation index is not really high, showing a value of 0.436); also between flexion-extension and HLA at initial DS, impact and finish (at finish particularly significant values of correlation are shown: -0.746 and -0.679 respectively with CHS and HLA, with p-value = 0.001); for the external-internal rotation, with CHS and HLA at address, and only with HLA at impact.



Graph. 4: Correlation trend between HLA and Right Hip Flexion-Exstension at finish for the different golfers.

Left Hip Angle: between flexion-extension and HLA at impact; between abduction-adduction and CHS and HLA at finish.

Hip Angular Velocity: with HLA at impact, for the right side; with CHS at early BS for the left side.

Right Hip Torque: for X component, with CHS at address and early BS, with H at initial DS..

Left Hip Torque: for X component, with H at late BS; for Y component, with CHS at late BS and impact, with HLA at impact, and with H at late BS (particularly significant value of correlation: 0.66 with p-value < 0.001); for Z component, with CHS at initial DS and impact, and finally with HLA at impact too.

Right Hip Table

	ANGLE									TORQUE									ANG. VEL.		
	F-E			AB-AD			E-I			X			Y			Z					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS	O						O	O		O		O				X	O				
EARLY BS	O									O											
LATE BS																					
INITIAL DS	O	O										O									
IMPACT	O	O						O												O	
EARLY FT	O																				
FINISH	Y	X																			

Table 12: Significant correlations between Right Hip (Angle, Torques and Angular Velocity) and Performing Factors

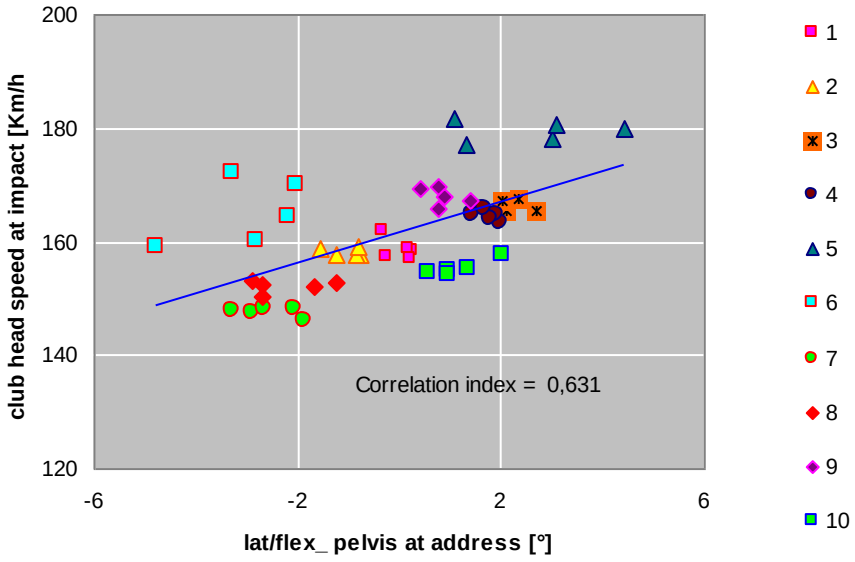
Left Hip Table

	ANGLE									TORQUE									ANG. VEL.		
	F-E			AB-AD			E-I			X			Y			Z					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS																					
EARLY BS																			O		
LATE BS												O	O		O						
INITIAL DS																O					
IMPACT		O											O	O		O	O				
EARLY FT																					
FINISH				Y	O																

Table 13: Significant correlations between Left Hip (Angle, Torques and Angular Velocity) and Performing Factors

3.2.1.4 Pelvis

Pelvis Angle: for the angle of flexion-extension, with CHS at early BS, late BS and initial DS, ad with HLA at initial DS; for lateral flexion, with CHS at address, late BS, impact and early FT, with HLA at early BS and late BS, and with H at initial DS, impact and finish; for right-left rotation, with CHS at late BS and with H at address.



Graph. 5: Correlation trend between CHS and Pelvis Lateral Flexion at address for the different golfers.

Pelvis Angular Velocity: no significant correlations were shown.

Pelvis Table

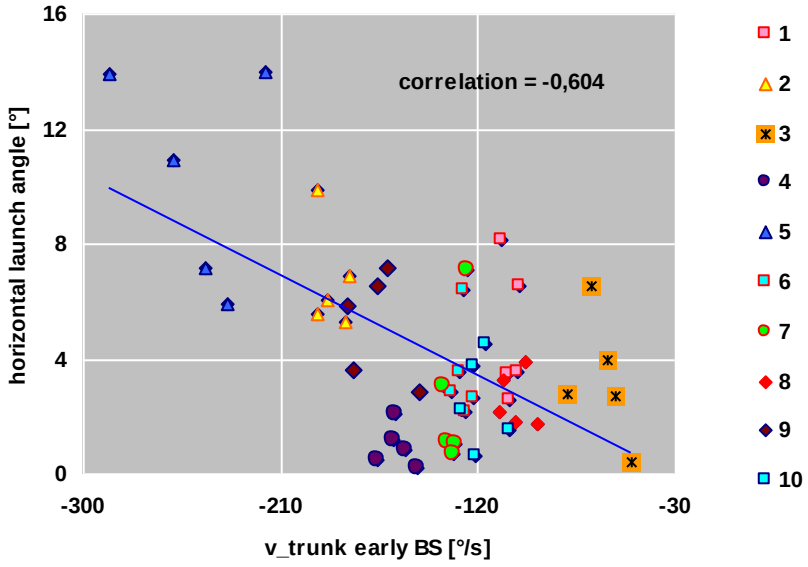
	ANGLE									ANG. VEL.		
	F-E			LAT.FLEX.			RIGHT-LEFT ROT.					
	CHS	HLA	H	C	HLA	H	CHS	HLA	H	CHS	HLA	F
ADDRESS				X					O			
EARLY BS	O				O							
LATE BS	O			O	O		O					
INITIAL DS	O	O				O						
IMPACT				O		O						
EARLY FT				O								
FINISH						O						

Table 14: Significant correlations between Pelvis (Angle and Angular Velocity) and Performing Factors

3.2.1.5 Trunk

Trunk Angle: for the angle of flexion-extension, with CHS at address, early BS, impact and finish, and with HLA at finish too; for lateral inclination, with CHS at address, initial DS, impact, early FT and finish, with HLA at early FT; for right-left rotation, with HLA at finish.

Trunk Angular Velocity: significant correlations were shown with CHS at early BS, late BS and initial DS, and with HLA at early BS, late BS and impact.



Graph. 6: Correlation trend between HLA and Trunk Angular Velocity at early BS for the different golfers.

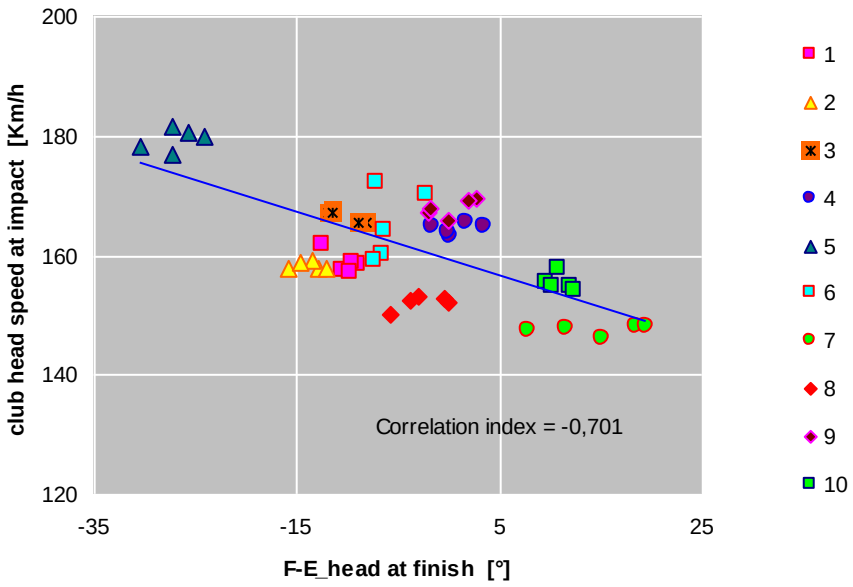
Trunk Table

	ANGLE									ANG. VEL.		
	F-E			LAT.FLEX.			RIGHT-LEFT ROT.					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS	O			O								
EARLY BS	O									O	X	
LATE BS										O	O	
INITIAL DS				O						O		
IMPACT	O			Y							O	
EARLY FT				Y	O							
FINISH	O	O		O				O				

Table 15: Significant correlations between Trunk (Angle and Angular Velocity) and Performing Factors

3.2.1.6 Head

Head Angle: for the angle of flexion-extension, with CHS and HLA at finish; for lateral inclination, with CHS and HLA at address, while with H at initial DS; for right-left rotation, with CHS and HLA at early FT, while with H at address, late BS and initial DS.



Graph. 7: Correlation trend between CHS and Head Flexion-Extension at finish for the different golfers

Head Angular Velocity: with CHS at early BS, and with HLA at address, early BS and late BS.

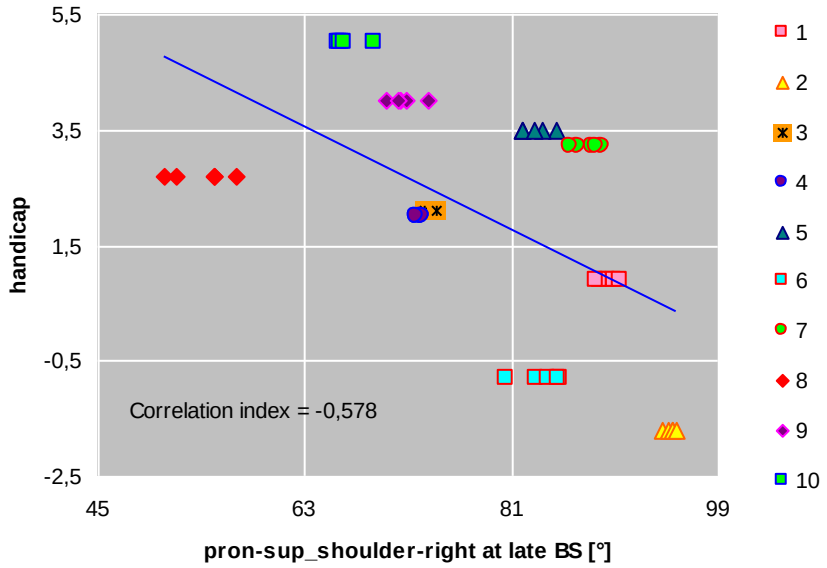
Head Table

	ANGLE									ANG. VEL.		
	F-E			LAT.FLEX.			RIGHT-LEFT ROT.					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS				X	O				O		O	
EARLY BS										O	X	
LATE BS									O		X	
INITIAL DS						O			O			
IMPACT												
EARLY FT							O	X				
FINISH	Y	X										

Table 16: Significant correlations between Head (Angle and Angular Velocity) and Performing Factors

3.2.1.7 Shoulders

Right Shoulder Angle: between the angle of flexion-extension and HLA at late BS and early FT, and with H at finish; for the pronation-supination angle, with HLA at finish and with H at late BS and initial DS.



Graph. 8: Correlation trend between H and Shoulder Pronation-Supination at late BS for the different golfers

Left Shoulder Angle: significant correlations were shown only with HLA at early BS.

Shoulder Angular Velocity: with CHS at impact, and with HLA at early BS and late BS, for the right side; with H at initial DS, for the left side.

Right Shoulder Table

	ANGLE						ANG. VEL.		
	F-E			PRON-SUP					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS									
EARLY BS								O	
LATE BS		O				O		X	
INITIAL DS						O			
IMPACT							O		
EARLY FT		X							
FINISH			O		O				

Table 17: Significant correlations between Right Shoulder (Angle and Angular Velocity) and Performing Factors

Left Shoulder Table

	ANGLE						ANG. VEL.		
	F-E			PRON-SUP					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS									
EARLY BS		O							
LATE BS									
INITIAL DS									O
IMPACT									
EARLY FT									
FINISH									

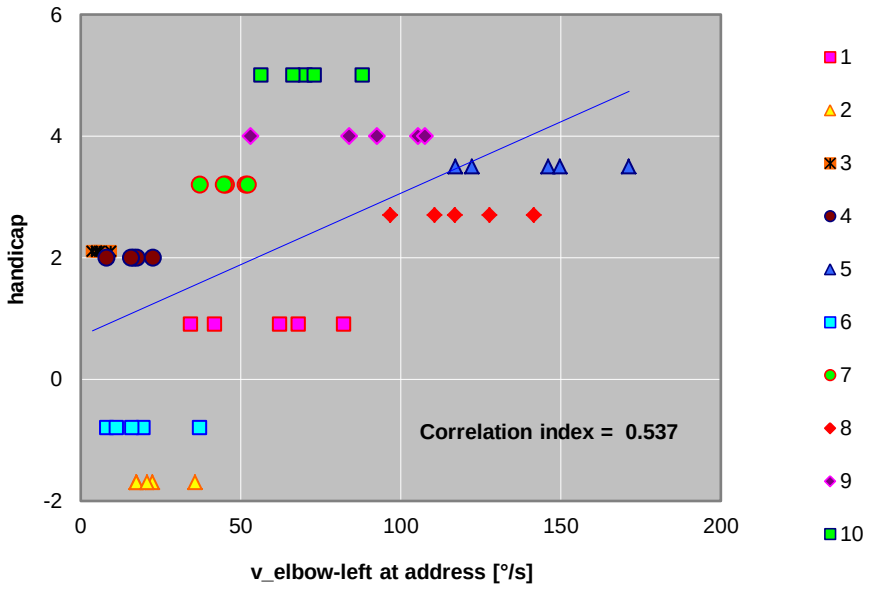
Table 18: Significant correlations between Left Shoulder (Angle and Angular Velocity) and Performing Factors

3.2.1.8 Elbows

Right Elbow Angle: between the angle of flexion-extension and CHS at address, initial DS and finish, and with H at address, early BS and impact; for external-internal rotation, with HLA at initial DS, impact and early FT.

Left Elbow Angle: between the angle of flexion-extension and HLA at early BS, late BS, initial DS, early FT and finish, and with H at impact; for external-internal rotation, with CHS and HLA at address, early BS and early FT.

Elbow Angular Velocity: with CHS at initial DS, and with HLA at early BS, late BS and initial DS, for the right side; with H at address and initial DS, for the left side.



Graph. 9: Correlation trend between H and Elbow Angular Velocity at address for the different golfers

Right Elbow Table

	ANGLE						ANG. VEL.		
	F-E			E-I					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS		O							
EARLY BS								O	
LATE BS								X	
INITIAL DS		O			O		X	O	
IMPACT			O		O				
EARLY FT					O				
FINISH		O							

Table 19: Significant correlations between Right Elbow (Angle and Angular Velocity) and Performing Factors

Left Elbow Table

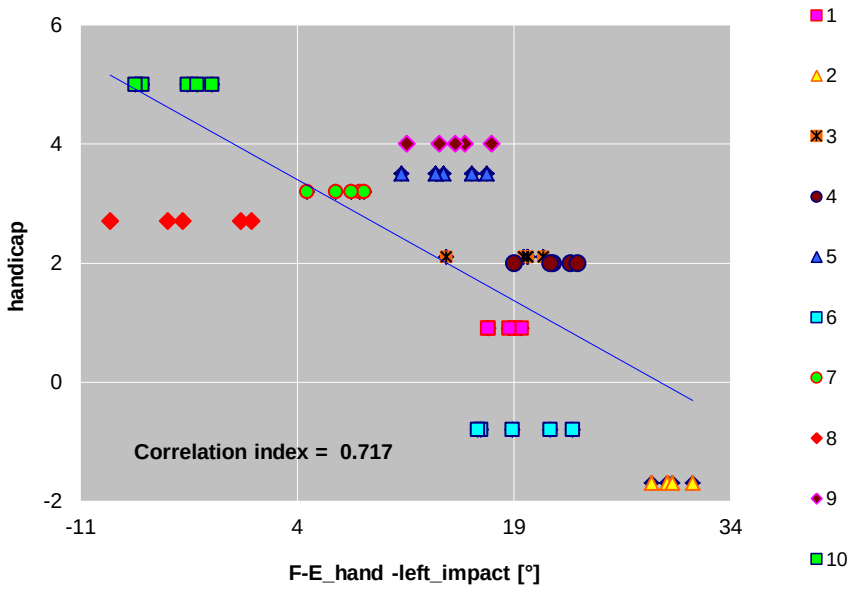
	ANGLE						ANG. VEL.		
	F-E			E-I					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS			O	X	O				O
EARLY BS		O	O	O	X				
LATE BS		O							
INITIAL DS		O							O
IMPACT			O						
EARLY FT		X		X	X				
FINISH		X							

Table 20: Significant correlations between Left Elbow (Angle and Angular Velocity) and Performing Factors

3.2.1.9 Hands

Right Hand Angle: between the angle of flexion-extension and CHS; moreover, very significant correlation were found for ulnar-radial deviation, both with CHS at address, initial DS and finish, and also with HLA at address, initial DS, impact (with correlation values respectively of -0.767, -0.714 and -0.715and p-values of 0.001), early FT and finish.

Left Hand Angle: between the angle of flexion-extension and H at early BS, initial DS impact and early FT; for ulnar-radial deviation, with HLA at address.



Graph. 10: Correlation trend between H and Hand Flexion-Extension at impact for the different golfers

Hand Angular Velocity: with CHS at address, with HLA at address and finish, for the right side; with CHS at address, with HLA at early FT, for the left side.

Right Hand Table

	ANGLE						ANG. VEL.		
	F-E			ULNAR-RADIAL DEV.					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS	O						O	O	
EARLY BS									
LATE BS									
INITIAL DS				O	Y				
IMPACT					Y	O			
EARLY FT								X	
FINISH	O			O	X				

Table 21: Significant correlations between Right Hand (Angle and Angular Velocity) and Performing Factors

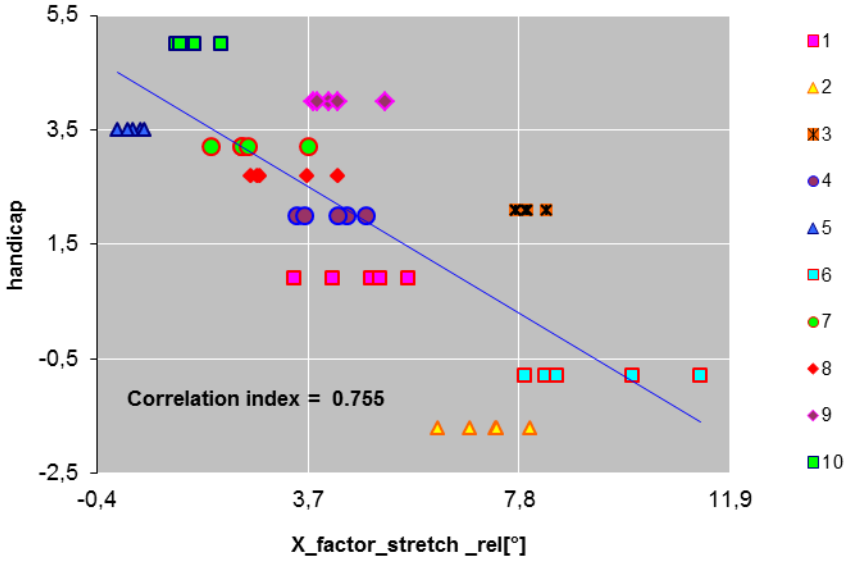
Left Hand Table

	ANGLE						ANG. VEL.		
	F-E			ULNAR-RADIAL DEV.					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H
ADDRESS					O		O		
EARLY BS			O						
LATE BS									
INITIAL DS			O						
IMPACT			Y					O	
EARLY FT			O						
FINISH									

Table 22: Significant correlations between Left Hand(Angle and Angular Velocity) and Performing Factors

3.2.1.10 X factor

X factor relative stretch shows a very significant correlation with H.



Graph. 11: Correlation trend between H and X Factor stretch rel. for the different golfers

X Factor Table

Position	Club Head Speed at Impact	Horizontal Launch Angle	Handicap
X_FACTOR_top			
X_FACTOR_stretch_rel			Y
X_FACTOR_mid_impact			

Table 23: Significant correlations between X Factor and Performing Factors

3.2.1.11 Time

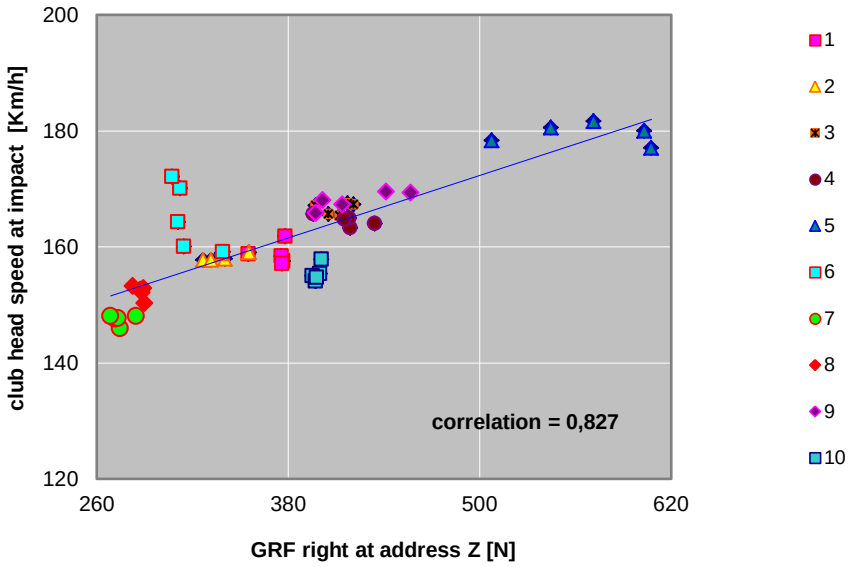
No significant correlations were shown between time and the elected performing factors.

3.2.1.12 Ground Reaction Forces

Both the right and left GRF showed that:

- at address, X and Y components were significantly related with CHS; the right x component was also significantly related with HLA
- at finish,Y components were significantly related with LA
- at Late BS, Z components were significantly related with H

Moreover, for the right side, X and Y components showed a correlation with CHS and HLA at early FT, while Y and Z components were significantly related with CHS at early and late BS. For the left side, in addition, Z components presented significant correlations with CHS at initial DS and impact (when also a significant correlation with HLA was reported).



Graph. 12: Correlation trend between CHS and Right GRF (Z component) at address for the different golfers.

3.2.2.13 Ground Reaction Torques

Significant correlations of the Ground Reaction Torques were reported with CHS at impact and with HLA at early FT.

GRF and GR Torques Table

	RIGHT FORCE									LEFT FORCE									TORQUE		
	X			Y			Z			X			Y			Z					
	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	H	CHS	HLA	F	CHS	HLA	H	CHS	HLA	H
ADDRESS		X		O			Y	O		X			X						O		X
EARLY BS				O			Y														
LATE BS				O			X		O									O			
INITIAL DS																X					
IMPACT																O	O		O		
EARLY FT	Y	O		O	O			O												O	
FINISH					O									O							

Table 24: Significant correlations between GRF (X, Y and Z components),GR Torques and Performing Factors

3.2.1.14 COP displacement

X component showed a significant correlation with HLA at finish, Y component with CHS at early BS, and Z component with H at late BS.

COP Table

	POSITION					
	X			Y		
	CHS	HLA	H	CHS	HLA	H
ADDRESS						
EARLY BS				O		
LATE BS						X
INITIAL DS						
IMPACT					O	
EARLY FT						
FINISH		O				

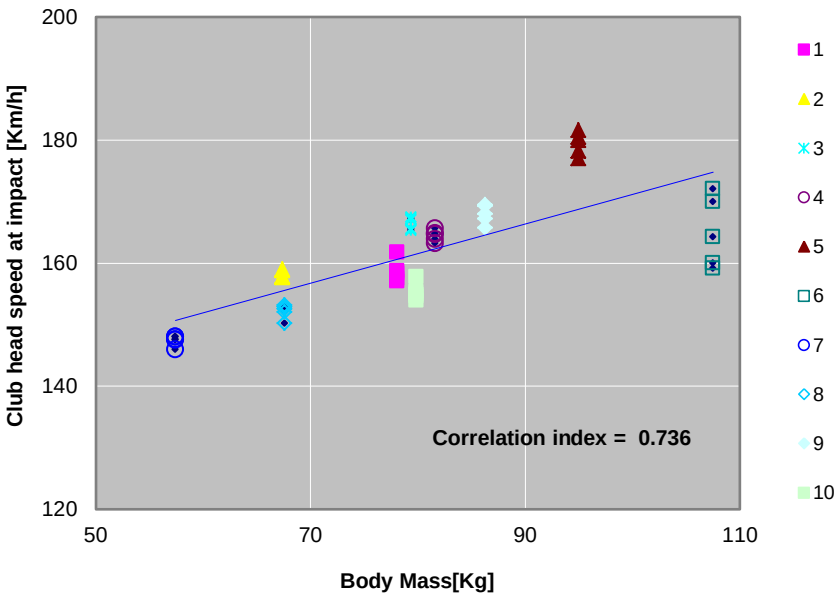
Table 25: Significant correlations between GRF (X, Y and Z components),GR Torques and Performing Factors

4.2.2 Analysis of the influence of the anthropometrical data on the golf performing factors

Anthropometrical variables presented significant correlations mainly with CHS. HLA did not show any significant correlation with the anthropometrical parameters analyzed, while H was only significant correlated with Trochanter belt height.

It has been reported that CHS increases with the following parameters:

- Body weight
- Body height
- Horizontal bust chest girth
- Right forearm length
- Right and left upper arm girth (particularly significant: 0.716 with p-value <0.001)
- Upper arm girth.
- Left and right forearm girth (particularly significant: 0.782 for the left side and 0.755for the right side, with p-value <0.001)
- Right and left horizontal thigh girth
- Left calf girth
- Biacromial_diameter (particularly significant: 0.763 with p-value <0.001)
- Right thigh length



Graph. 13: Correlation trend between CHS and Body Mass for the different golfers

Anthropometrical – Performing factors Table

	CHS	HLA	H
Body_mass_kg	Y		
Body_height_cm	O		
Crotch_height_cm			
Knee_height_cm			
Bust_chest_girth_horizontal_cm	X		
Arm_length_left_cm			
Arm_length_right_cm			
Upper_arm_length_left_cm			
Upper_arm_length_right_cm			
Forearm_length_left_cm			
Forearm_length_right_cm	O		
Upper_arm_girth_left_cm	Y		
Upper_arm_girth_right_cm	X		
Forearm_girth_left_cm	Y		
Forearm_girth_right_cm	Y		
Thigh_girth_right_horizontal_cm	O		
Calf_girth_left_cm	O		
Calf_girth_right_cm			
Trochanter_belt_height_cm	O		O
Biacromial_diameter_cm	Y		
Hand_length_right_cm			
Thigh_length_right_cm	O		
Thigh_length_left_cm			
Hand_palm_length_right_cm			
Hand_palm_length_left_cm			
Leg_length_right_cm			
Ulnar_styloid_height_left_cm			
Trochanter_average_height_cm			
Trochanter_height_left_cm			
Hand_width_right._cm			
Foot_length_cm			

Table 26: Significant correlations between anthropometrical parameters and golf performing factors

Between the data of somatotypes, a significant correlation with performing factors was shown for Mesomorphy, which attested the influence of musculation in the ball velocity and generally in increasing golf swing performance: correlation indexes of 0.567 and -0.569 with p-values <0.001 were presented with CHS and H, respectively.

Somatotype- Performing factors Table

	CHS	HLA	H
Endomorphy			
Mesomorphy	O		
Ectomorphy			

Table 27: Significant correlations between somatotypes and golf performing factors

4.2.3 Analysis of the influence of the anthropometrical data on the biomechanical variables

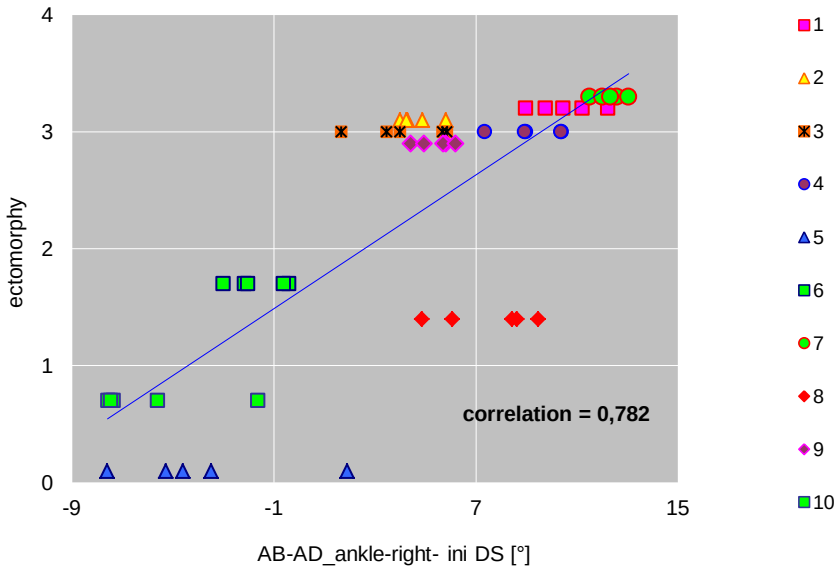
All the biomechanical variables analyzed in the present study were statistically correlated with five anthropometrical data:

- Endomorphy
- Mesomorphy
- Ectomorphy
- Body height
- Body mass

These parameters were elected among all the anthropometrical data collected because they were considered representative of the physical type of the subjects. Significant correlations were obtained for:

4.2.3.1 Ankle

Right Ankle Angle: flexion-extension at address decreases with the increment of endomorphy; at impact, it decreases with the increment of body height. Abduction-adduction, instead, shows a decrement with the increment of endomorphy at late BS; it also shows a correlation with ectomorphy (significantly increasing with its increment during the first phases of the swing) and with body mass (decreasing when it increases from early BS until initial DS). During the first phases of the swing, also external-internal rotation decreases with the increment of endomorphy and body mass, while it increases with ectomorphy (during address, early and late BS and finish).



Graph. 14: Correlation trend between Ectomorphy and Right Ankle Abduction-adduction at initial DS for the different golfers

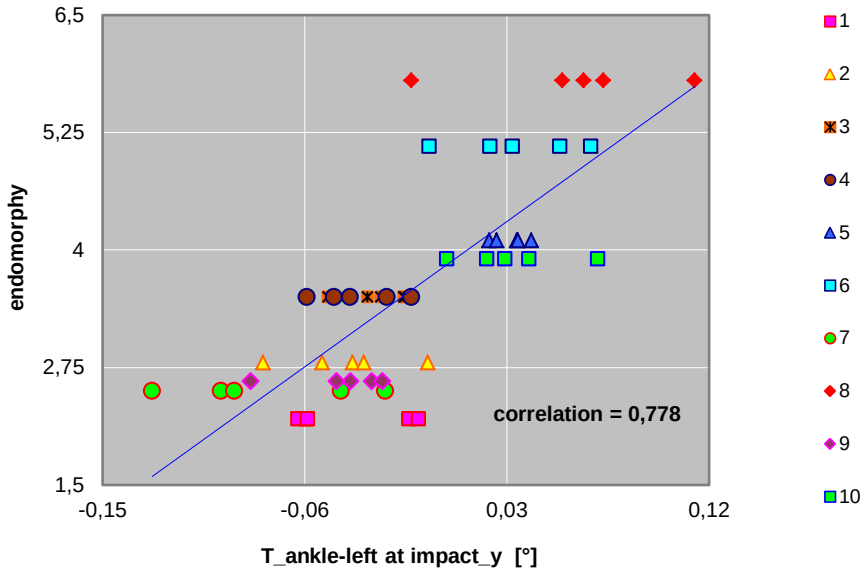
Left Ankle Angle: flexion extension at impact and early FT decreases with the increment of ectomorphy; at initial DS and early FT, it decreases with body height. Abduction-adduction decreases with the increment of endomorphy at initial DS, while it increases with endomorphy at finish; it increases with ectomorphy (at impact), with height (at address) and body mass (at address, early BS and early FT). External-internal rotation decreases with the increment of endomorphy at the beginning of the swing, and with body mass at address, impact, early FT and finish; on the other hand, it increases with ectomorphy (at address and impact) and height (during the late BS and initial DS).

Ankle Angular Velocity: the velocity was influenced by ectomorphy (both for the right and left side, respectively at early BS, and at address and early FT), and by height at early FT (only for the left ankle).

Right Ankle Torque: X component shows a decrement with ectomorphy at early FT and with body height at early BS, late BS and initial DS. Y component decreases with ectomporhy at early BS, and with height at early and late BS. Z component decreases with ectomorphy at early FT and with body mass during the first parts of swing, until the initial DS.

Left Ankle Torque: At initial DS, X component increases with endomorphy, mesomorphy and body mass; it decreases with ectomorphy at early and late BS. Y component increases

with endomorphy at initial DS and impact, and with body mass at address; it decreases with ectomorphy at address, initial DS and impact. Z component increases with endomorphy at late BS and early FT; it decreases with mesomorphy at initial DS and with ectomorphy from early BS to early FT; it also decreases with height (at early FT) and with body mass (at initial DS).



Graph. 15: Correlation trend between Endomorphy and Left Ankle Torque, Y component, at impact for the different golfers

Right Ankle Table

	ANGLE															TORQUE														ANG: VEL.				
	F-E					AB-AD					E-I					X					Y					Z								
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS	o							o			x		x		y		o													o				
EARLY BS								x		o	o		o		x				o				x	o					x			o		
LATE BS						o		y		o	o		o		x				o	o				x					x					
INIT. DS								y		x					x				x										o					
IMPACT				o							x																							
EARLY FT											o												o					y						
FINISH													o																						

Table 28: Significant correlations between Right Ankle (Angle, Angular Velocity and Torques) and Anthropometrical Factors

Left Ankle Table

	ANGLE															TORQUE														ANG: VEL.				
	F-E					AB-AD					E-I					X					Y					Z								
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS									x	o	x		o		o								o		o	o					o			
EARLY BS										o	o							o										o						
LATE BS														o				x		o						o		o						
INIT. DS				o		o								o		o	o			o	o		y				o			c				
IMPACT			x	o				x					o		y						y		y					x							
EARLY FT			x							o					o											o		o	o			x	o		
FINISH						o																												

Table 29: Significant correlations between Left Ankle (Angle, Angular Velocity and Torques) and Anthropometrical Factors

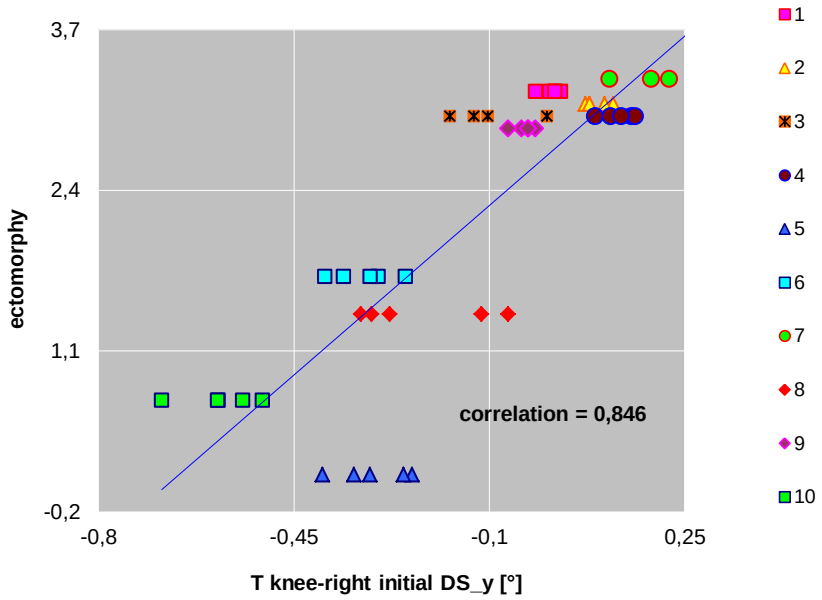
4.2.3.2 Knee

Right Knee Angle: at address, flexion-extension decreases with endomorphy and increases with height; this angle also decreases with body mass at early and late BS. External-internal rotation shows a decrement with the increasing of body mass for the whole movement until impact.

Left Knee Angle: flexion-extension increases with endomorphy at finish and decreases with mesomorphy at address; from impact to finish, it shows a decrement with ectomorphy and height. External-internal rotation decreases with the increment of endomorphy at early FT and finish; besides, it strongly decreases with body mass during the whole swing until the moment of early FT.

Knee Angular Velocity: at initial DS, the velocity of the right knee decreases with mesomorphy, height and body mass. The left knee's velocity instead decreases with ectomorphy and body mass at impact, and with height at address.

Right Knee Torque: X component shows a decrement with ectomorphy at early BS and an increment with height (at impact) and body mass (at early BS, initial DS and impact). Y component decreases with endomporhy at initial DS and impact, and with body mass from early BS until the impact; it increases with ectomorphy from early BS until the impact, and with height at impact. At impact, Z component decreases with endomorphy and increases with body mass; from early BS until the initial DS, it shows an increment with ectomporhy and a decrement with body mass.



Graph. 16: Correlation trend between Ectomorphy and Right Knee Torque, Y component, at initial DS for the different golfers

Left Knee Torque: X component decreases with endomorphy (at early and late BS) and with mesomorphy (at late BS and finish); with ectomorphy, it increases at early and late BS while it decreases at impact; with body mass, it increases at impact. Y component decreases with mesomorphy at initial DS and impact, with height at initial DS and with body mass at late BS and initial DS; it increases with ectomorphy at initial DS and finish. Z component increases with endomorphy at early BS; it decreases with mesomorphy (at initial DS and finish) and with body mass (at initial DS and impact).

Right Knee Table

	ANGLE										TORQUE															ANG: VEL.				
	F-E					E-I					X					Y					Z									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS	o			o						o																				
EARLY BS					o					x			o					o		x			o		y					
LATE BS					o					x								o		y			x		x					
INIT. DS										o					x			y		o			o		o					o
IMPACT										y				o	o	o		o						y						
EARLY FT																														
FINISH																														

Table 30: Significant correlations between Right Knee (Angle, Angular Velocity and Torques) and Anthropometrical Factors

Left Knee Table

	ANGLE										TORQUE															ANG: VEL.				
	F-E					E-I					X					Y					Z									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS		o								x											o								o	
EARLY BS										y	o		o								o									
LATE BS										x	x		o					o		x										
INIT. DS										x							x		o	x		y			o					
IMPACT			y	o						o			x		o		x								y			o		
EARLY FT				o		o				o																				
FINISH	x		o	o		o						o						o				o								

Table 31: Significant correlations between Left Knee (Angle, Angular Velocity and Torques) and Anthropometrical Factors

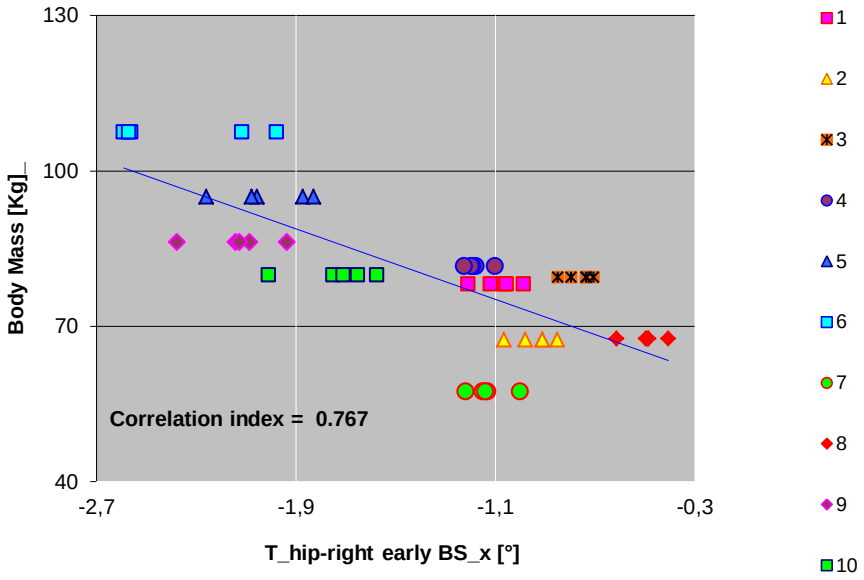
4.2.3.3 Hip

Right Hip Angle: the right hip flexion extension angle shows only e decrement with height at early and late BS. During the impact and early FT, abduction-adduction is influenced by endomorphy (with a negative coefficient of correlation), mesomorphy, ectomorphy and height (with a positive coefficient of correlation); it shows a decrement with height at early and late BS. External-internal rotation shows an increment with ectomorphy at finish and a decrement with height at early FT.

Left Hip Angle: flexion extension at finish decreases with the increment of endomorphy, it increases with ectomorphy (at impact and finish) and with height (at impact and early FT). Abduction-adduction shows an increment with mesomorphy at finish, with height at late BS and with body mass at early and late BS; it decreases with ectomorphy at impact and early FT. External-internal rotation decreases with the increment of endomorphy at early and late BS; it increases with ectomorphy during the first phases of the swing until the early FT; moreover, at early FT, it shows an increment with height.

Hip Angular Velocity: for the right side, the velocity decreases with endomorphy at impact, with mesomorphy at initial DS, and with height at late BS. For the left side, at initial DS it shows a decrement with endomorphy, mesomorphy and body mass; at late BS and early FT, it decreases with ectomorphy.

Right Hip Torque: X component decreases with body mass at early and late BS. Y and Z component increase with body mass at early BS and at early FT, respectively.



Graph. 17: Correlation trend between Body Mass and Right Hip Torque , X component, at early BS for the different golfers

Left Hip Torque: X component increases with ectomorphy at late BS; it decreases with mesomorphy at late BS and with ectomorphy at early and late BS; it also increases with ectomorphy at impact. From late BS until the impact, Y component decreases with

ectomorphy and increases with body mass. Z component decreases with mesomorphy (at impact and finish) and with body mass (at impact).

Right Hip Table

	ANGLE															TORQUE														ANG: VEL.				
	F-E					AB-AD					E-I					X					Y					Z								
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS																						O		O											
EARLY BS					O					O										Y					O										
LATE BS					O					X										X													X		
INIT. DS																																O			
IMPACT						X	O	X	X																					O					
EARLY FT						X	O	X	X					O															O						
FINISH													O																						

Table 32: Significant correlations between Right Hip (Angle, Angular Velocity and Torques) and Anthropometrical Factors

Left Hip Table

	ANGLE															TORQUE														ANG: VEL.				
	F-E					AB-AD					E-I					X					Y					Z								
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS													O			O													O						
EARLY BS										O			O					O																	
LATE BS									O	O			X			O	O	O					X		O								O		
INIT. DS													O										X		O						X	O			O
IMPACT			X	X				O										O					X		O		O			O					
EARLY FT				X				O					X	O																			O		
FINISH	O		O				X			X																	O								

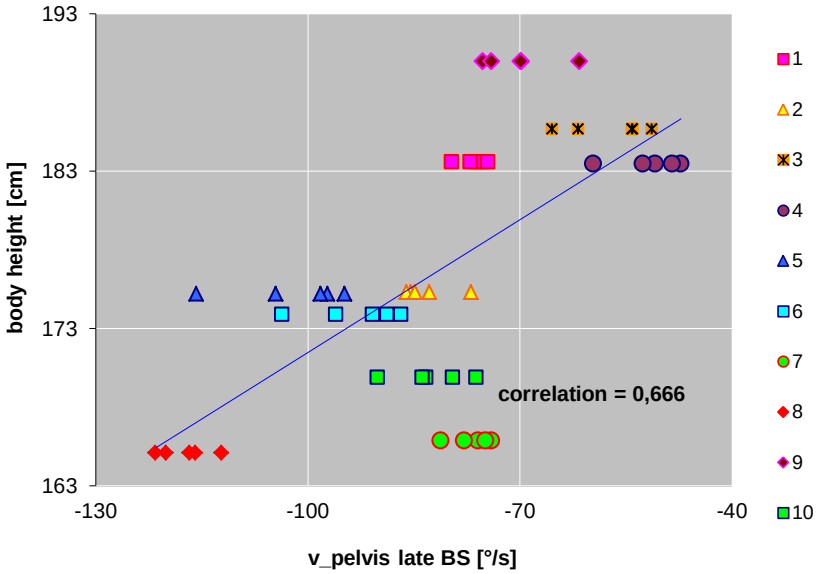
Table 33: Significant correlations between Left Hip (Angle, Angular Velocity and Torques) and Anthropometrical Factors

4.2.3.4 Pelvis

Pelvis Angle: the angle of flexion-extension shows an increment with mesomorphy at impact and finish and with body mass at impact. Lateral flexion decreases with

endomorphy at impact. Right-left rotation increases with mesomorphy at finish and decreases with body height at initial DS.

Pelvis Angular Velocity: at address, it increases with endomorphy; at early BS, it increases with height; at late BS, it decreases with endomorphy while it increases with ectomorphy and height; at initial DS, it decreases with endomorphy, mesomorphy and body mass.



Graph. 18: Correlation trend between Body Height and Pelvis Angular Velocity at Late BS for the different golfers

Pelvis Table

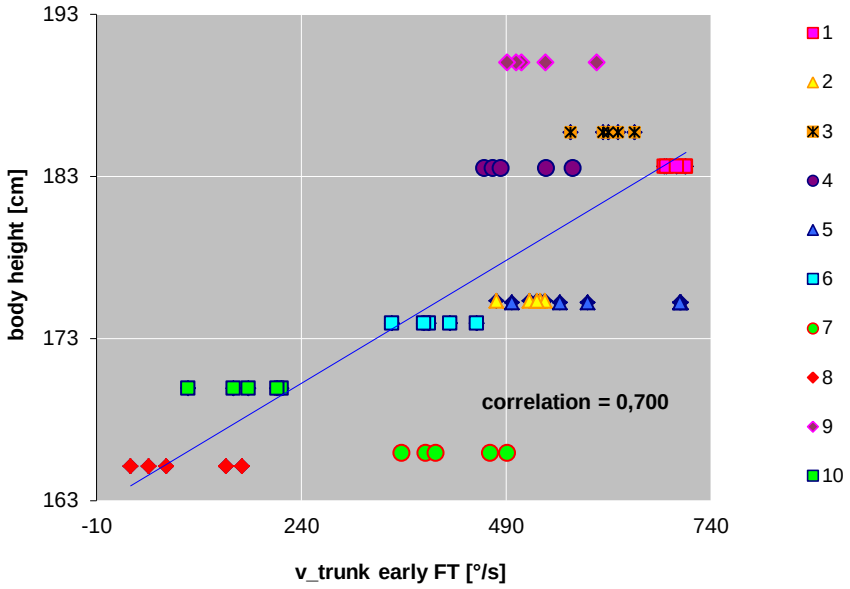
	ANGLE															ANG: VEL.				
	F-E					Lat. Flex.					Right-Left rot.									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS																O				
EARLY BS																			O	
LATE BS																X		X	X	
INIT. DS														O		O	O			O
IMPACT		O				O														
EARLY FT																				
FINISH		O										O								

Table 34: Significant correlations between Pelvis (Angle and Angular Velocity) and Anthropometrical Factors

4.2.3.5 Trunk

Trunk Angle: flexion- extension decreases with the increment of endomorphy during the first parts of the swing (until the initial DS); it increases with ectomorphy at initial DS and with body height from early BS until the impact. Lateral flexion shows a decrement with ectomorphy at finish. Right-left rotation was influences by endomorphy (from late BS until the impact, with a positive correlation index), ectomorphy and height (at impact with a negative correlation index).

Trunk Angular Velocity: at initial DS, it increases with body mass; at impact, it decreases with endomorphy; at early FT, it decreases with endomorphy while increasing with mesomorphy and height.



Graph. 19: Correlation trend between Body Height and Trunk Angular Velocity at early FT for the different golfers

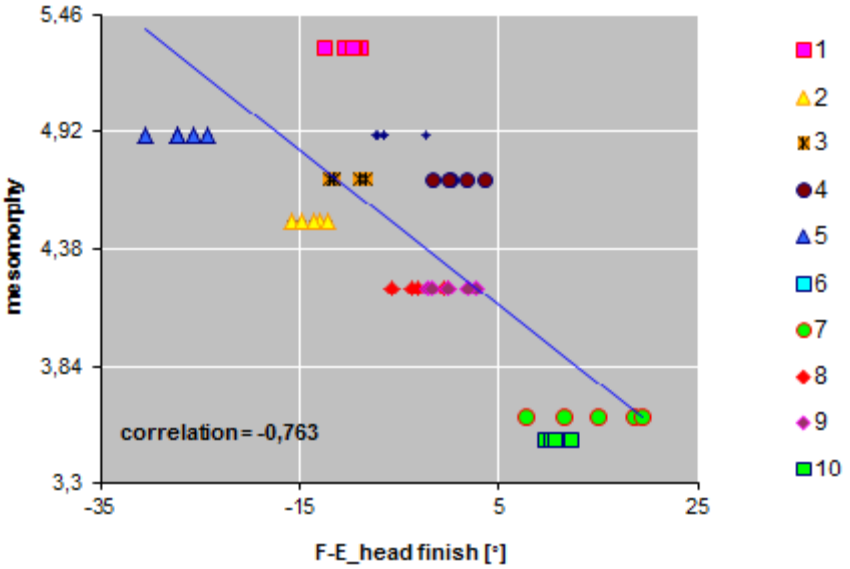
Trunk Table

	ANGLE															ANG: VEL.				
	F-E					Lat. Flex.					Right-Left rot.									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS	o																			
EARLY BS	o			o																
LATE BS	o			o							o									
INIT. DS	x		x	o							o									x
IMPACT											x		o	x		o				
EARLY FT																x	x		y	
FINISH								o												

Table 35: Significant correlations between Trunk (Angle and Angular Velocity) and Anthropometrical Factors

4.2.3.6 Head

Head Angle: the angle of flexion-extension increases with mesomorphy for the whole movement of swing; at address, it shows a decrement with endomorphy ad an increment with ectomorphy; it decreases with height (from initial DS until early FT) and with body mass (from address until early FT).Lateral inclination increases with endomorphy at early BS and impact; at initial DS, it increases with mesomorphy while decreasing with it at finish; it also decreases with ectomorphy at address, impact and early FT; besides, it decreases with height from impact to finish while it increases with it at initial DS; furthermore, it increases with body mass at early BS and initial DS while it shows a decrement with it at finish. Right-left rotation ectomorphy, height and body mass (respectively at address, early BS and impact), but it decreases with ectomorphy at early FT.



Graph. 20: Correlation trend between mesomorphy and Head flexion-extension at finish for the different golfers

Head Angular Velocity: it increases with mesomorphy at early FT, and decreases with ectomorphy at address; with height, it decreases at initial DS and increases at early FT; moreover, it shows a decrement with body mass at initial DS.

Head Table

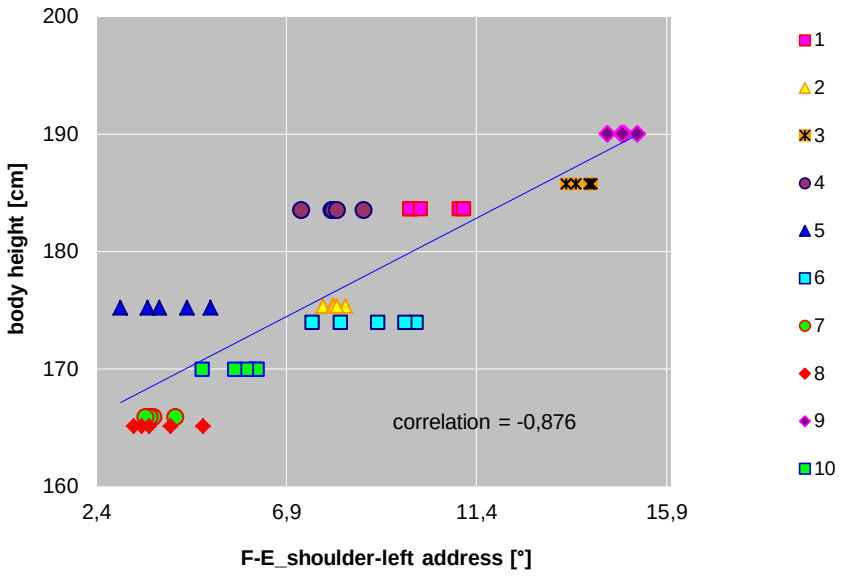
	ANGLE															ANG: VEL.				
	F-E					Lat. Flex.					Right-Left rot.									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS	o	o	o		x			o					o					x		
EARLY BS		x			x									o						
LATE BS		x			x													o		
INIT. DS		o		x	o		y		o	o									x	o
IMPACT		o		o				x	o						o					
EARLY FT		o		o	o			o	y				o				o		o	
FINISH		y					o		o	y										

Table 36: Significant correlations between Head (Angle and Angular Velocity) and Anthropometrical Factors

4.2.3.7 Shoulder

Right Shoulder Angle: at address, flexion-extension decreases with endomorphy while increasing with it at initial DS; this angle also increases with mesomorphy (at early FT), with ectomorphy (at address at impact, but instead it decreases at initial DS), and with height (at address, impact and early FT).Pronation-supination significantly decreases with endomorphy for the whole movement of swing, showing also a decrement with body mass at finish.

Left Shoulder Angle: flexion extension increases with endomorphy at initial DS, and with ectomorphy at address and finish (but it shows a decrement with it at initial DS); during the address and early BS it increases with height, while decreasing with it at impact. External-internal rotation does not show any significant correlation with anthropometrical parameters.



Graph. 21: Correlation trend between Body Height Left Shoulder Flexion-extension at address for the different golfers

Shoulder Angular Velocity: for the right side, the velocity shows a decrement with endomorphy at address; in addition, it increases with endomorphy at early FT, with mesomorphy at early BS and with ectomorphy at initial DS. At impact, the left knee's velocity increases with mesomorphy and height; it also decreases with height during address and backswing (early and late).

Right Shoulder Table

	ANGLE										ANG: VEL.				
	F-E					Pron.-Sup.									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS	x		o	y		y					o				
EARLY BS						y		o				o			
LATE BS						x									
INIT. DS	x		y			y							o		
IMPACT			o	x		o					o				
EARLY FT		o		y											
FINISH						o				o					

Table 37: Significant correlations between Right Shoulder (Angle and Angular Velocity) and Anthropometrical Factors

Left Shoulder Table

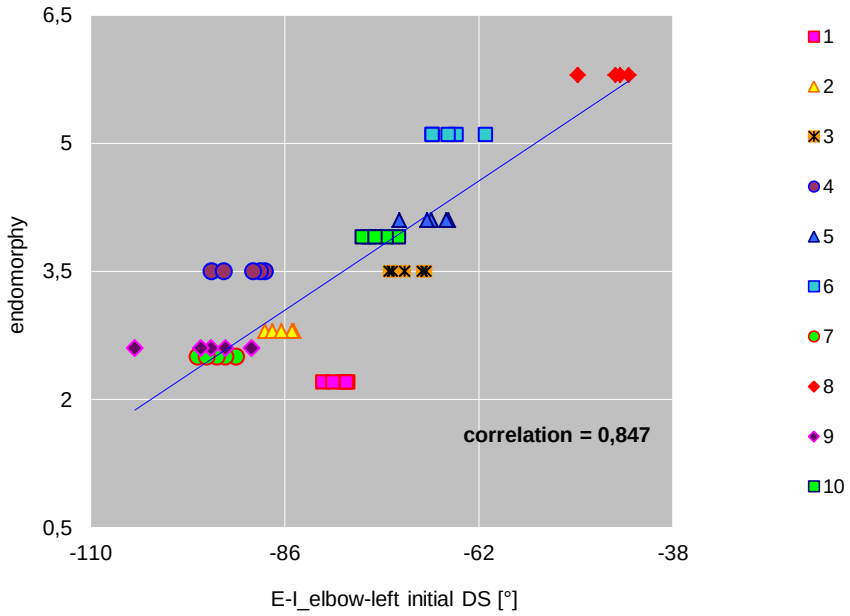
	ANGLE										ANG: VEL.				
	F-E					Pron.-Sup.									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS			o	y										o	
EARLY BS				x										o	
LATE BS														o	
INIT. DS		o		x											
IMPACT					o							o		o	
EARLY FT															
FINISH			o												

Table 38: Significant correlations between Left Shoulder (Angle and Angular Velocity) and Anthropometrical Factors

4.2.3.8 Elbow

Right Elbow Angle: flexion-extension shows an increment with endomorphy at address and a decrement with it at early FT. External-internal rotation only significantly increases with endomorphy at early BS.

Left Elbow Angle: the left elbow flexion extension angle decreases with mesomorphy (at impact) and with height (at impact and early FT). External-internal rotation increases with ectomorphy (at late BS, initial Ds and finish) and decreases with height (from impact to finish).



Graph. 22: Correlation trend between Endomorphy and Left Elbow External-internal Rotation at initial DS for the different golfers

Elbow Angular Velocity: for the right side, velocity increases with endomorphy (at early FT), with mesomorphy (at impact) and with height (at impact); in addition, it decreases with ectomorphy (at address, late BS and initial DS) and with height (at early FT). For the left side, velocity decreases with ectomorphy (at address) and height (at late BS), while it increases with them at impact (for ectomorphy) and early FT (for both ectomorphy and height).

Right Elbow Angle

	ANGLE										ANG: VEL.				
	F-E					Ext.-Int. Rot.									
	E	M		H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS													X		
EARLY BS	O					O									
LATE BS													O		
INIT. DS													O		
IMPACT												O		O	
EARLY FT	O										O			O	
FINISH															

Table 39: Significant correlations between Right Elbow (Angle and Angular Velocity) and Anthropometrical Factors

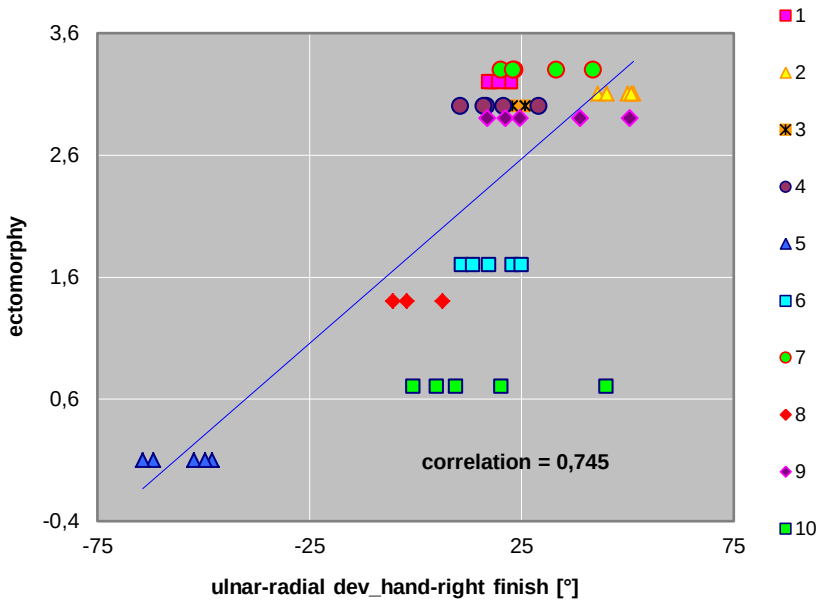
Left Elbow Angle

	ANGLE										ANG: VEL.				
	F-E					Ext.-Int. Rot.									
	E	M		H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS													X		
EARLY BS															
LATE BS						O								O	
INIT. DS						Y									
IMPACT		O		X					O				O		
EARLY FT				O					O				X	O	
FINISH						X			O						

Table 40: Significant correlations between Left Elbow (Angle and Angular Velocity) and Anthropometrical Factors

4.2.3.9 Hands

Right Hand Angle: flexion-extension increases with endomorphy (during the initial DS and impact) and with body mass (at late BS and initial DS).Ulnar-radial deviation decreases with the increment of endomorphy (at initial DS), mesomorphy (at early BS and early FT) and body mass (at address and impact), while it increases with ectomorphy during the initial DS and finish.



Graph. 23: Correlation trend between Ectomorphy and Right Hand Ulnar-radial Deviation at finish for the different golfers

Left Hand Angle: flexion extension shows a decrement with endomorphy at late BS, while during the last phases of swing (form impact to finish) it increases with mesomorphy, ectomorphy and height; it also shows a significant increment with body mass at finish). Ulnar-radial deviation decreases with the increment of endomorphy (are finish) and body mass (at the beginning of the swing, from address to late BS), and increases with ectomorphy at finish.

Hand Angular Velocity: velocity shows and decrement with the increasing of endomorphy and ectomorphy (respectively at late BS-impact and at address) and an increment with ectomorphy too, at impact, for the right hand. For the left hand, it decreases with endomorphy at impact and with ectomorphy at address, while increasing at impact with it and with height.

Right Hand Angle

	ANGLE										ANG: VEL.				
	F-E					Uln.-Rad. Dev.									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS										y			x		
EARLY BS							o								
LATE BS					o						o				
INIT. DS	x				o	o		x							
IMPACT										o	o		x		
EARLY FT							x								
FINISH								y							

Table 41: Significant correlations between Right Hand (Angle and Angular Velocity) and Anthropometrical Factors

Left Hand Angle

	ANGLE										ANG: VEL.				
	F-E					Uln.-Rad. Dev.									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS										o			o		
EARLY BS										o					
LATE BS	o			o						o					
INIT. DS															
IMPACT			o	o							x		o	y	
EARLY FT		o	o	x											
FINISH		o		o	y	y		o							

Table 42: Significant correlations between Left Hand (Angle and Angular Velocity) and Anthropometrical Factors

4.2.3.10 X factor

X factor top shows a decrement with mesomorphy, while X factor relative stretch shows an increment with ectomorphy.

X Factor Table

Position	Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
X_FACTOR_top		o			
X_FACTOR_stretch_rel			o		
X_FACTOR_mid_impact					

Table 43: Significant correlations between X Factor and Anthropometrical Factors

4.2.3.11 Time

The time of downswing shows an increment with the increment of endomorphy and mesomorphy.

Time Table

Position	Endomorphy	Mesomorphy	Ectomorphy	Body Height	Body Mass
t_swing_s					
t_backswing_s					
t_downswing_s	o	o			

Table 44: Significant correlations between Time and Anthropometrical Factors

4.2.3.12 Ground Reaction Forces

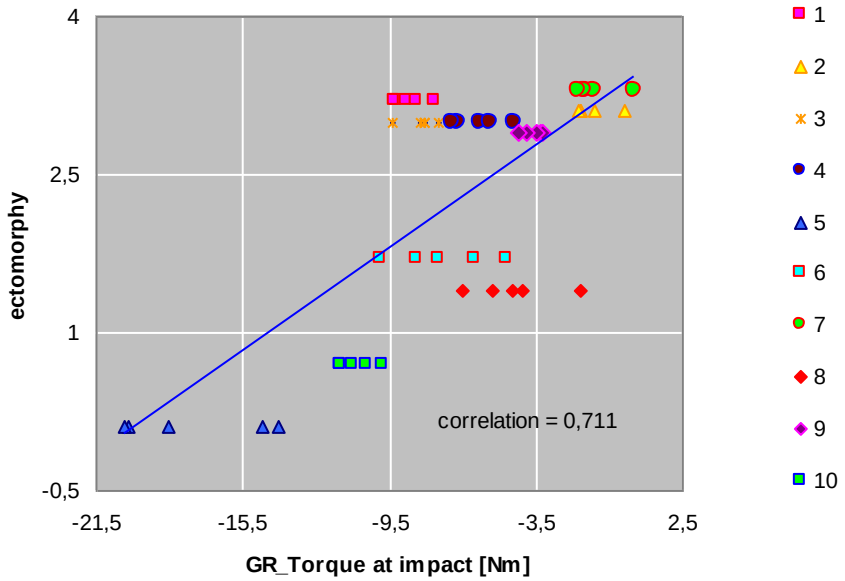
Right GRF: at initial DS, X component increases with mesomorphy and body mass; it also decreases with height at early FT. Y component decreases with mesomorphy (at address), ectomorphy (at early FT and finish), height and body mass (at late BS and initial DS). Z component shows a decrement with ectomorphy (with early and late BS) and increases with height (at address and initial DS) and body mass (during the first phases of swing, until the early FT).

Left GRF: X component decreases with mesomorphy (at initial DS), ectomorphy (at impact while showing an increment with it at early BS) and body mass (at initial DS). Y component increases with endomorphy (at early FT), mesomorphy (at initial DS and impact), ectomorphy (during the late BS, initial DS and finish), height (at address and initial DS) and body mass (at address). Z component shows a decrement with endomorphy (at late BS) and ectomorphy (at impact) and an increment with endomorphy (at address),

mesomorphy and ectomorphy (at late BS), height (at late BS and finish) and body mass (at address and impact).

4.2.3.13 Ground Reaction Torques

GR Torques show an increment with ectomorphy at address, and also increase with during the initial part of the swing (from the early BS until the moment of impact).



Graph. 24: Correlation trend between Ectomorphy and GR Torque at impact for the different golfers

GRF and GR Torques Table

	RIGHT															LEFT														TORQUE				
	X					Y					Z					X					Y					Z									
	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W	E	M	C	H	W
ADDRESS							X							O	O									O	O	O				X					
EARLY BS									X				O		Y			O																	Y
LATE BS									O	Y			X		Y								O			O	X	X	O						Y
INIT. DS					O				O	X				O	O		X			O		O	O	O											X
IMPACT															O			X				X						Y		O			Y		O
EARLY FT				O				X													O														
FINISH								O															X						O						

Table 45: Significant correlations between GRF (X, Y and Z components), GR Torques and Anthropometrical Factors

4.2.3.14 COP displacement

X component shows an increment with endomorphy (at address and initial DS); moreover, it decreases with ectomorphy and body body mass for almost the whole movement of swing. Y component decreases with endomorphy (at address and impact), mesomorphy and ectomorphy (at late BS), while it shows an increment with the increasing of ectomorphy and height (at the moment of impact).

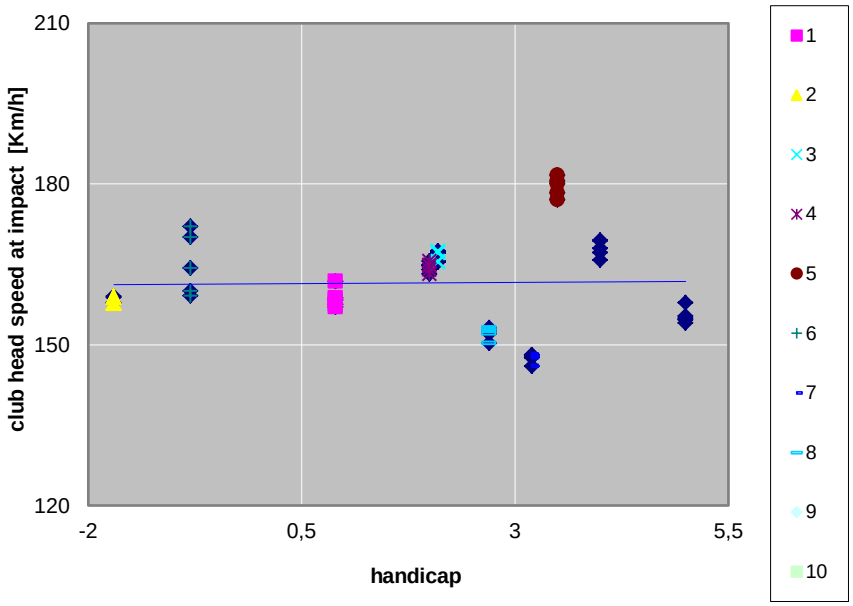
COP Table

	POSITION									
	X					Y				
	E	M	C	H	W	E	M	C	H	W
ADDRESS	O			Y		O				
EARLY BS				X						
LATE BS				Y			O	O		
INIT. DS	X			X						
IMPACT			Y	O		O		X	O	
EARLY FT			X	O						
FINISH			Y							

Table 46: Significant correlations between COP (X and Y components) and Anthropometrical Factors

4.2.4 Analysis of the mutual influence of the golf performing factors

Among the performing factors, significant correlations were reported only between CHS and HLA. Although it was not significant, the correlation between CHS and H is reported in Graph. 25 to evidence the trend of these two parameters.



Graph. 25: Correlation trend between CHS and H for the different golfers

5. DISCUSSION

One of the main goals of the present work was to develop and analyse the biomechanical motion of the swing, the anthropometric characteristics of the golfer, the sportive performance and the correlation between them, in order to obtain criteria to design an optimal golf swing for each golfer. Comparisons with other authors were considered very important for the evaluation of the results obtained, thus a survey of the extensive literature available today has been performed. In order to reach the research objectives, a certain methodology was defined, which was based on:

1. **Study Sample**

Ten semi-professional golfers with similar ages, trainings and abilities (the handicap vary only from -1.7 to 5) have been analyzed. It has consented a comparison of various aspects of the swing minimizing artefacts due to differences between the players (for example, the same golf club was used for all the tests). Although the number of subjects was restricted, the total amount of tests performed allows obtaining a sufficient statistical power (>80%).

2. **Experimental Procedure**

The use of a photogrammetric system associated with two dynamometric platforms consented to develop a complete kinetic and kinematic analysis. Compared to other studies, the sample frequency of 250 Hz was considerably high and the number of cameras (ten) was sufficient to monitor adequately the whole test area. The 3D scanner for anthropometric evaluation has allowed an analysis (that has not been performed in the current literature) of the influence of the anthropometrical factors on biomechanical variables that bring useful information for golf coachers and players. The use of 42 markers (with 4 specific for calibration) monitored by the ten cameras has allowed the development of a complete biomechanical model of the golfers performing the swing. It has consented an analysis of the movement of lower limbs (hips, knees, ankles), pelvis, trunk, upper limbs (shoulders, elbows, hands) and finally head.

3. **Parameters of analysis**

One of the main characteristics of this work was to collect a massive number of different types of variables:

- all the principal dimensions of the whole body and body segments have been measured
- the somatotype factors have been calculated for the different golfers
- many articular angles and angular velocity, as well as the low extremities articular torques have been evaluated
- ground reaction forces, ground reaction torques, significant times of swing and centre of pressure displacements have been collected

Kinetic and kinematic analysis have been developed in literature, but not all the aspects of kinetics and kinematics have been investigated, as for instance the ground reaction torques, or ankle and head ROM.

Some anthropometrical parameters were evaluated by other authors, but a study of the somatotypes together with a 3D assessment of the whole body has not been performed in golf literature. Besides, the relation between somatotype and anthropometric parameters with biomechanical factors has not been investigated.

With the methodology described above, and considering that the present analysis was performed by considering statistical correlation index between couples of meaningful parameters not less than 0.45 and p-value not greater than 0.001, significant results have been obtained in many fields:

a) **Handicap vs Club Head Speed at impact**

In literature, CHS was considered a valid measure of golf performance, and its relation with H was investigated, as proposed by Fradkin et al. [14] and reported in fig.1 (Par. 2.2.2). In the present work, as reported in the results, no significant correlations between H and CHS were found. However, H values of golfers of this study cover only a limited part of the range of fig.1, namely from - 1.7 to + 5. This can explain the fact that the correlation between the two parameters is apparently low if compared to what obtained in literature. Moreover, the value of H not only depends on the velocity of the ball, but it is also

correlated with ball direction and repeatability of measurement: it can explains the poor influence of the only CHS on the range of handicap studied in the current work.

b) **Biomechanical vs Performing Factors**

First of all, the present analysis of results has been focused on the movement and positions assumed by four body parts:

- Pelvis
- Trunk
- Shoulders
- Hands

It has been taken into consideration that the examined golfers were all semi-professionals, part of the same school of high performance. In their training, they have been focusing on timing, to reach a correct sequence of the movement of shoulder, trunk, pelvis and hand. Most of them have shown to move more pelvis, while an optimal shoulder ROM has still not been totally developed. This is visible in the results. Infact, from the present analysis it has been obtained that:

- Pelvis angles and angular velocity influence swing performance more than shoulder position or velocity
- Trunk movement strongly influences ball velocity
- X factor relative stretch increases with the increase of the player ability

These results have been compared with current literature.
Firstly, some authors [2][34] report that often teaching professionals seek to maximize upper torso rotation during the backswing while minimizing pelvic rotation in their students. This technique, differently from the one analyzed in the present study, results in the fact that none of the pelvic position or velocity variables were correlated with ball velocity. It suggests that the type of training of the players surely influences their golf performance and that, in particular, a movement that emphasizes the motion of pelvis generates more influence of pelvis and hips on the performing factors respect to the influence of shoulders.

Secondly, regarding the trunk, in the present results CHS is significantly influenced by the trunk angular velocity during backswing and downswing (when trunk rotation increases), which results in a strong correlation between the lateral flexion of the trunk and CHS at impact and in the following phases. There are other authors [8], instead, who report that trunk forward tilt angle should be kept nearly constant from downswing towards the follow-through, whilst in the present study this tendency is not verified. However, the result found here is supported by Myers et al. [34], who affirm that the current teaching philosophy of the golf swing emphasizes an increase in torso coiling during the backswing, which theoretically results in increased impulse during the downswing, and subsequent increased ball velocity.

In addition, the role of X factor has been examined, being directly calculated with the separation between pelvis and trunk and their relative rotation. The fact that X factor relative stretch decreases with the increment of H means that the lower handicap a player has the better X factor he can perform. The other components of X factor examined (X factor_top and X factor_mid impact) did not show any significant relation with biomechanical factors. This result is supported by Healy et al. [24], who report that X factor angle at the top of the backswing may not be the most important phase for this variable. In literature, X factor was more strongly correlated with ball velocity than pelvis or trunk rotation [8][30][34]; in the present work the results do not support this thesis, probably because of the semi-professionality of the golfers. A training focused on the increment of X factor could help in enhancing the performance of the players, as reported by Mc Hardy et al. [31]

Finally, results show that the right hand ulnar-radial deviation has a significantly influence on the direction of the ball (measurable through the HLA), and also on its velocity. This finding is confirmed in literature, as reported by various authors [21][36][41][45]. In particular, Nesbit [36] affirms that the torques and range of motion of the wrists are important factors in generating club head velocity and that the actions of the wrists identified the better golfer more than the speed of the hands. However, in our study the correlation between CHS and right hand angle showed negative values, which means that velocity decreases with the increment of the wrist angle, while Chu et al. [8] found that a

greater wrist joint angle delivered a positive effect to ball velocity. This may be correlated with the tendency of remaining flexed instead of extended reported in elbow angles.

Beyond all these aspects, other important conclusions can be sum up:

- Although the ROM of this joint was not analysed in the previous literature, a very important role during the movement of swing is played by ankle. It can be noticed that whereas in the right ankle more numerous correlations are present between the various parameters (angles, angular velocity, torques) and CHS, in the left ankle the predominant factor is H. It means that the role of the right ankle is related to generate force in the golfer and thus club head velocity. The rotation of the left ankle, instead, influences the ability of the player, resulting more related, thus, with factors as repeatability and control.

- Elbows show a particularly significant relation with performing parameters, and particularly with the ball direction. Broer [4] reports that the more extended a golfer keeps their arms the greater the velocity the club head is capable of generating since the club head travels through a longer arc in a given time and therefore moves faster. In the present study, though, it can be noticed that elbows remain prevalently flexed during the entire movement of swing (particularly the right elbow): this can explains the fact that a correlation between CHS and flexion-extension has not been reported, whilst this angle (together with external-internal rotation) significantly influences ball direction.

- Head movement particularly influences the direction of the ball. It can be noticed that angular velocity, in fact, is strongly correlated with HLA and also that the various angles are well correlated to CHS, HLA and H during the different phases of swing. It means that swing performance can be effectively influenced by this parameter that has not been considered in literature: especially, a good control of the movement of the head should be maintained in order to obtain a better control of the golf shot.

- COP displacement is poorly related to H, even though Sell et al. [43] found that players with $H < 0$ had significantly better balance than players with higher H.

Maybe, the low correlation reported was due to the fact that the examined golfers were semi-professional, having similar H mainly around 0 or more. Moreover, as discussed by Lephart et al. [27] it is possible that including a greater number of subjects would have resulted in statistical significance in balance variables.

c) Anthropometrical vs Performing Factors

CHS were significantly correlated with several anthropometrical parameters, although no one showed correlations with HLA and only few with H. Effectively, the velocity of the ball seems to be more correlated to the physique of the subjects, respect to their ability or to the direction they give to the ball. To prove that the force of the players effectively influence the parameter of CHS, it has been attested that, among the somatotype parameters, mesomorphy has shown influence to CHS, result that is supported by literature. In fact, in Hellstrom et al.[19], in their review, affirm that there is an association between physique and driving distance and that muscle power is important to consider when training for CHS. Keogh et al.[25], instead, found that it was apparent that no anthropometric variables were significantly correlated to CHS: probably, the accuracy of results depends also on the different parameters taken into consideration. According to that, it can be reported that in the present study, more correlations have been found between measures of body segment girth and diameters compared with data of lengths. In [25], instead, more measures of body segments lengths were made, together with indicators of fat and body mass that have not been considered in the present analysis.

d) **Anthropometrical vs Biomechanical Parameters**

Even if this relation was not investigated by other authors, the results found show many significant relations between anthropometrical parameters and biomechanical variables. Overall, the results show that golfers with different physical characteristics have different swing motions. Therefore, some important aspects should be pointed out:

- Ectomorphy influences the way of execute the gesture of swing: the present findings show that golfers with ectomorph somatotypes tend to use a “two-plane swing”, which is characterised by arms that hang closer to the body on a more upright plane and shoulders coiling in a flatter, more rotational plane. In fact, ectomorph players has bigger GR Torques and minor X component in GRF

compared with more mesomorph or endomorph subjects, as can be seen in Table 45. Therefore, also flexion-extension of shoulders is strongly influenced by ectomorphy: in particular at initial DS, the increasing of ectomorphy means a significant decreasing of this angle.

- Endomorphy has a strong influence on the movement of pelvis and trunk: in particular, angular velocity of these body parts decreases with the increment of the endomorph somatotype in subjects, as well as the flexion-extension of trunk that results reduced with the increasing of this characteristic. Endomorph somatotype, instead, is poorly related with the biomechanical variables associated to the articular systems of lower extremities (ankles, knees and hips).
- Body mass significantly influences the lower extremities joints ROM. The present findings show that the articular angles of ankles and knees are significantly influenced by the mass of the player during the various phases of swing. Thus, the ROM of these joints, which have shown to influence the performance of swing, vary depending on the thinnes of the subject.

6. CONCLUSIONS AND FUTURE DEVELOPMENTS

This study is aimed to contribute with the methodology proposed for analyzing the golf swing to improve the knowledge of the swing motion and thus the performance of each player.

Some conclusions can be made to summarize the present work:

1. An anthopometric assessment has been performed, furnishing precise parameters of the physical characteristics of the golfers, which also gives the opportunity of defining their proper somatotypes
2. A kinematic and kinetic approach has been maintained to understand all the biomechanical variables involved in swing motion: to study them, photogrammetric system with dynamometric platforms are adequate if the sample frequency is considerably high and the number of cameras is sufficient to register the movement.
3. A statistical analysis has been developed, pointing in two main directions: furnishing a descriptive analysis of all the variables studied, and showing the correlations between all the different types of parameters. Both these analysis are useful to fully understand the characteristics of the movement of swing, giving the possibility of evidencing the parameters that were more significant to enhance the performance of golfers during their swing.
4. Three groups of variables have been studied: anthropometrical, biomechanical and performing factors. Correlations between all these types of parameters have shown significant results, confirming the influence of these types of factors on the swing motion.
5. In particular, the relation existing between anthropometrical and biomechanical factors has not been explored before, and it has brought very interesting results. It means that the somatotype of the golfers, as well as his physical parameters, effectively influence the range of motion, velocity and torques of articular angles involved in golf swing, as well as kinetic variables as GRF, GR Torques and COP displacement.

6. All the information collected in the present study can be used to develop a golf analysis system that furnish a valid implement for players and coachers to improve golf technique and performance.

Nevertheless, there were several limitations to the current work.

First, the restricted number of players has limited the statistical study: in the descriptive analysis, standard deviations have shown high values; also for the definition of significant correlations, the dimension of the study sample has to be taken into consideration. However, the statistical power of analysis was sufficiently high to carry on the assessment.

Second, the golfers were all semi-professional. On the one hand, it means that they have similar levels, which do not allow an analysis of the influence of handicap on performing factors. On the other hand, their technique still has to improve: it can influence the analysis of some parameters, as the X factor. Nevertheless, the similar conditions of players has been an advantages in comparing them without the influence of external factors related with different abilities and physical conditions.

Third, due to the huge amount of data collected, only some aspects were evaluated while others, as the kinetic chain and the repeatability of the gesture, have not been taken into consideration. It was considered, though, that the descriptive analysis of the selected variables together with the analysis of their correlations was sufficient to develop an exhaustive analysis of the golf swing motion.

Forth, while the performance goal golfers pursue is the driving distance, in our indoor laboratory setting it can only be estimated with club head speed and launch angle. However, many authors report that there is a direct proportionality between the displacement of golf shot and the club head speed at the moment of impact, so this factor together with launch angle was considered the most accurate for driving performance of golfers.

Having considered the limits of the current study, future research may be directed at:

- increasing the study sample
- including golfers with different levels of ability (professionals and amateurs) instead of only semi-professional players
- evaluating also the kinetic chain as an important biomechanical factor

- assessing also the repeatability of the gesture as an indicator of the ability of the golfer
- using a radar system for monitoring the direction and velocity of the ball

Finally, it can be concluded that the double goal of evaluating swing motion with a biomechanical and anthropometric approach has been reached. An optimal golf swing is the result of many biomechanical and anthropometrical features, and both these aspects should be considered in each phase of the swing to help enhance performance in golf. This work can be considered as a preliminary study for the definition of the "optimal" swing, furnishing a useful means for golfers and coachers to evaluate many aspects of training and performance in golf.

APPENDIX I - Biomechanical characteristics of the sample

1. Ankle

1.1 Right ankle angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION-EXTENSION(+) Flexion(-) Extension				
ADDRESS	4.636	4.710	-2.747	16.515
EARLY BS	-0.187	4.910	-8.649	11.200
LATE BS	-0.276	5.020	-8.130	11.826
INITIAL DS	2.242	5.300	-8.831	12.657
IMPACT	-14.338	8.690	-34.540	0.169
EARLY FT	-20.847	8.040	-35.992	-6.558
FINISH	-43.089	12.670	-59.504	15.693
ADUCCION-ABDUCCION (-) Adduction (+) Abduction				
ADDRESS	4.821	4.880	-5.964	20.603
EARLY BS	1.741	5.360	-9.861	13.326
LATE BS	2.337	5.110	-8.506	12.398
INITIAL DS	4.156	5.870	-7.600	13.043
IMPACT	10.101	8.890	-5.153	24.900
EARLY FT	6.295	10.620	-15.215	26.248
FINISH	2.938	9.810	-22.321	19.485
ROTATION(-)External(+)Internal				
ADDRESS	-0.863	3.510	-8.365	5.396
EARLY BS	0.614	4.190	-10.547	5.795
LATE BS	1.503	4.270	-10.233	7.705
INITIAL DS	2.505	4.160	-8.551	8.148
IMPACT	-0.866	4.190	-8.148	6.593
EARLY FT	-2.921	4.970	-11.344	6.835
FINISH	-5.121	7.070	-19.485	6.977

Appendix Table 1: Descriptive analysis of the right ankle angles

1.2 Left ankle angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION-EXTENSION (+) Flexion (-) Extension				
ADDRESS	1.537	3.050	-5.271	6.855
EARLY BS	8.758	4.810	2.146	20.216
LATE BS	12.111	4.580	4.543	20.852
INITIAL DS	14.461	5.210	1.860	21.836
IMPACT	-14.702	13.980	-44.232	0.996
EARLY FT	-15.881	11.440	-40.449	0.934
FINISH	-7.305	3.790	-16.885	0.872
ADUCTION-ABDUCTION (-) Adduction (+) Abduction				
ADDRESS	3.613	3.440	-2.366	10.585
EARLY BS	8.319	4.560	-0.606	18.936
LATE BS	9.493	4.590	0.006	17.205
INITIAL DS	9.230	4.980	0.267	19.646
IMPACT	7.316	6.730	-3.510	25.018
EARLY FT	4.670	7.500	-7.573	24.782
FINISH	6.396	11.630	-13.586	34.402
ROTATION(-)External(+)Internal				
ADDRESS	0.246	4.560	-10.988	8.550
EARLY BS	-0.576	4.640	-11.013	10.296
LATE BS	-1.715	5.090	-15.162	10.777
INITIAL DS	-3.359	5.540	-14.059	9.915
IMPACT	5.009	5.130	-7.315	13.727
EARLY FT	5.005	5.040	-6.237	14.159
FINISH	7.774	5.560	-5.267	16.753

Appendix Table 2: Descriptive analysis of the left ankle angles

1.3 Ankle angular velocity

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
RIGHT				
ADDRESS	18.434	12.540	1.905	57.805
EARLY BS	29.332	16.500	7.087	95.009
LATE BS	28.437	22.010	8.045	106.222
INITIAL DS	46.560	31.250	9.163	153.179
IMPACT	240.421	75.020	76.927	415.066
EARLY FT	118.871	55.600	47.729	346.289
FINISH	55.083	38.390	7.521	174.270
LEFT				
ADDRESS	11.990	6.870	1.732	29.920
EARLY BS	43.783	19.060	7.413	83.223
LATE BS	28.708	18.780	5.234	102.839
INITIAL DS	43.736	26.970	13.116	139.327
IMPACT	187.385	97.370	24.293	445.789
EARLY FT	146.221	87.590	22.005	366.744
FINISH	29.966	21.790	3.712	92.853

Appendix Table 3: Descriptive analysis of the ankle angular velocity

1.4 Right ankle torques

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
X_component				
ADDRESS	-0.464570	0.1876	-0.85290	-0.16350
EARLY BS	-0.776064	0.2583	-1.22054	-0.29962
LATE BS	-0.566480	0.3129	-1.07940	-0.08087
INITIAL DS	-0.455028	0.2297	-1.02385	-0.14376
IMPACT	-1.011233	0.2132	-1.37433	-0.59116
EARLY FT	-0.937400	0.2776	-1.47512	-0.41945
FINISH	0.003305	0.1637	-0.41247	0.38850
Y_component				
ADDRESS	-0.026238	0.0323	-0.11423	0.02303
EARLY BS	0.038375	0.0602	-0.14024	0.15343
LATE BS	0.069997	0.0632	-0.12820	0.16104
INITIAL DS	0.048110	0.0634	-0.11467	0.17631
IMPACT	-0.199754	0.1789	-0.46918	0.10864
EARLY FT	-0.262086	0.2353	-0.76819	0.05619
FINISH	0.133312	0.1511	-0.23356	0.35933
Z_component				
ADDRESS	-0.077155	0.0602	-0.17975	0.03807
EARLY BS	-0.211893	0.1199	-0.41837	0.01894
LATE BS	-0.236048	0.1220	-0.45929	-0.00403
INITIAL DS	-0.239391	0.0928	-0.41574	-0.11054
IMPACT	-0.121713	0.0931	-0.31709	0.04831
EARLY FT	-0.069914	0.0827	-0.21463	0.15255
FINISH	0.058647	0.0743	-0.15079	0.23635

Appendix Table 4: Descriptive analysis of the articular torque of the right ankle

1.5 Left ankle torques

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
X_component				
ADDRESS	-0.390350	0.1137	-0.61032	-0.17953
EARLY BS	-0.164462	0.0806	-0.36805	-0.04064
LATE BS	-0.177219	0.0995	-0.38594	-0.04654
INITIAL DS	-0.332769	0.1477	-0.63477	-0.12456
IMPACT	-0.260205	0.1758	-0.58442	0.14799
EARLY FT	-0.284982	0.2239	-0.71928	0.23424
FINISH	-0.350027	0.1798	-0.83626	0.00272
Y_component				
ADDRESS	-0.043214	0.0435	-0.13864	0.04284
EARLY BS	-0.052148	0.0286	-0.10920	-0.00543
LATE BS	-0.047868	0.0354	-0.13260	-0.00113
INITIAL DS	0.001513	0.0433	-0.05161	0.12650
IMPACT	-0.011038	0.0507	-0.12801	0.11359
EARLY FT	0.058971	0.0961	-0.15387	0.36060
FINISH	0.178126	0.2815	-0.13589	0.91615
Z_component				
ADDRESS	-0.073540	0.0632	-0.19267	0.01301
EARLY BS	-0.058314	0.0389	-0.11999	0.02491
LATE BS	-0.066794	0.0372	-0.12630	0.00612
INITIAL DS	0.000829	0.0899	-0.14182	0.14866
IMPACT	-0.008281	0.0979	-0.14483	0.27524
EARLY FT	0.026628	0.1026	-0.13931	0.23415
FINISH	0.181499	0.1448	-0.39093	0.51748

Appendix Table 5: Descriptive analysis of the articular torque of the left ankle

2. Knee

2.1 Right knee angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION-EXTENSION (+) Flexion (-) Extension				
ADDRESS	23.528	7.350	11.130	42.000
EARLYBS	18.475	7.460	5.523	35.460
LATE BS	17.945	8.090	5.188	35.540
INITIAL DS	22.134	7.710	8.270	35.970
IMPACT	22.860	9.500	-3.213	35.800
EARLY FT	17.128	7.720	3.902	35.670
FINISH	23.321	9.720	10.462	83.530
ROTATION (-) External (+) Internal				
ADDRESS	-8.701	5.510	-23.596	1.310
EARLY BS	-15.759	7.820	-36.419	-4.330
LATE BS	-20.806	6.850	-38.200	-11.370
INITIAL DS	-22.638	5.760	-39.192	-14.940
IMPACT	8.623	7.530	-11.171	19.140
EARLY FT	14.393	7.880	-2.656	25.260
FINISH	-7.498	13.600	-59.240	22.640

Appendix Table 6: Descriptive analysis of the right knee angles

2.2 Left knee angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION-EXTENSION (+) Flexion (-) Extension				
ADDRESS	22.635	4.660	14.553	34.480
EARLYBS	29.736	7.940	17.657	42.600
LATE BS	33.949	8.050	24.299	46.360
INITIAL DS	38.306	8.810	23.010	52.050
IMPACT	11.766	6.000	-4.126	25.990
EARLY FT	10.563	2.320	5.658	16.700
FINISH	9.605	6.020	1.493	23.440
ROTATION (-) External (+) Internal				
ADDRESS	-7.120	7.550	-27.159	2.560
EARLY BS	-1.132	7.460	-18.772	8.630
LATE BS	2.426	8.970	-15.300	16.870
INITIAL DS	4.285	8.120	-12.951	15.160
IMPACT	-20.035	10.590	-42.353	-5.670
EARLY FT	-17.834	12.480	-43.961	-1.840
FINISH	-31.591	10.920	-55.049	-10.520

Appendix Table 7: Descriptive analysis of the left knee angles

2.3 Knee angular velocity

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
RIGHT				
ADDRESS	21.103	19.770	4.534	90.066
EARLYBS	52.345	17.800	20.621	92.866
LATE BS	32.493	14.700	10.353	69.622
INITIAL DS	76.405	45.870	22.703	172.813
IMPACT	267.223	79.180	122.194	480.428
EARLY FT	152.903	51.960	48.218	262.583
FINISH	41.269	36.970	3.468	211.508
LEFT				
ADDRESS	15.302	13.340	2.807	83.434
EARLY BS	56.195	25.410	13.453	133.125
LATE BS	53.052	32.500	9.044	219.366
INITIAL DS	76.610	35.540	16.159	157.705
IMPACT	199.326	81.530	33.712	357.465
EARLY FT	143.008	73.050	28.031	302.674
FINISH	31.371	28.250	5.507	189.552

Appendix Table 8: Descriptive analysis of the knee angular velocity

2.4 Right knee torques

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
X_component				
ADDRESS	0.256525	0.2166	-0.19810	0.68426
EARLY BS	-0.009671	0.2290	-0.38950	0.53402
LATE BS	-0.015209	0.2428	-0.53992	0.40308
INITIAL DS	-0.370806	0.2180	-0.68071	0.18432
IMPACT	-0.448652	0.3314	-0.97575	0.34539
EARLY FT	-0.364040	0.3555	-116.634	0.33637
FINISH	0.106310	0.6225	-111.735	168.790
Y_component				
ADDRESS	0.124923	0.0620	0.00988	0.24949
EARLY BS	0.146884	0.2254	-0.29090	0.49967
LATE BS	0.092199	0.2408	-0.32918	0.54408
INITIAL DS	-0.109102	0.2424	-0.68681	0.25684
IMPACT	0.711947	0.2570	0.22613	123.585
EARLY FT	0.898825	0.2425	0.28743	128.813
FINISH	0.738462	0.2938	0.11863	171.885
Z_component				
ADDRESS	-0.006188	0.0460	-0.09771	0.13754
EARLY BS	-0.092604	0.1236	-0.40960	0.07516
LATE BS	-0.154495	0.1355	-0.44207	0.03535
INITIAL DS	-0.124814	0.1144	-0.38959	0.03146
IMPACT	0.246528	0.1256	-0.00242	0.52535
EARLY FT	0.393743	0.1096	0.12617	0.60081
FINISH	0.313395	0.1588	-0.00475	0.82848

Appendix Table 9: Descriptive analysis of the right knee articular torques

2.5 Left knee torques

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
X_component				
ADDRESS	0.058845	0.1035	-0.10746	0.27999
EARLY BS	0.056010	0.1007	-0.15073	0.31322
LATE BS	0.192393	0.1262	-0.00632	0.43244
INITIAL DS	0.564252	0.2218	0.11725	0.98475
IMPACT	-0.306964	0.3534	-0.86727	0.66681
EARLY FT	-0.406372	0.3036	-0.90568	0.38703
FINISH	-0.391017	0.4290	-125.917	0.43995
Y_component				
ADDRESS	-0.066881	0.0895	-0.27045	0.07841
EARLY BS	-0.008222	0.0818	-0.15351	0.17028
LATE BS	0.157144	0.1001	-0.03112	0.31191
INITIAL DS	0.744330	0.2608	0.31642	124.193
IMPACT	-0.106416	0.3114	-0.70649	0.69277
EARLY FT	0.021408	0.2709	-0.56336	0.52931
FINISH	-0.320503	0.4087	-100.861	0.42475
Z_component				
ADDRESS	0.023746	0.0271	-0.03791	0.08120
EARLY BS	0.004059	0.0236	-0.05083	0.04208
LATE BS	0.007066	0.0419	-0.05705	0.09927
INITIAL DS	0.125963	0.1279	-0.09278	0.32236
IMPACT	0.002552	0.1269	-0.40773	0.16148
EARLY FT	0.119232	0.0915	-0.05017	0.32794
FINISH	0.203016	0.1829	-0.15648	0.55011

Appendix Table 10: Descriptive analysis of the left knee articular torques

3. Hip

3.1 Right hip angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION-EXTENSION (-) Flexion (+) Extension				
ADDRESS	-39.572	6.520	-52.674	-28.010
EARLYBS	-39.494	6.930	-52.832	-29.800
LATE BS	-40.079	7.580	-53.176	-28.980
INITIAL DS	-43.799	8.980	-62.253	-30.870
IMPACT	-5.658	7.860	-14.806	19.970
EARLY FT	6.980	6.660	-2.815	24.900
FINISH	16.971	6.920	2.251	31.010
ADDUCTION-ABDUCTION (-) Adduction (+) Abduction				
ADDRESSS	4.393	3.030	-0.854	12.560
EARLY BS	-5.878	4.710	-15.188	3.840
LATE BS	-11.662	4.110	-19.447	-2.730
INITIAL DS	-15.246	3.860	-23.326	-8.050
IMPACT	20.508	4.630	11.220	27.940
EARLY FT	20.040	3.660	13.072	28.180
FINISH	5.204	6.960	-12.555	19.880
ROTATION (+) External (-) Internal				
ADDRESS	1.440	7.980	-13.425	17.350
EARLY BS	-18.143	7.190	-30.308	-6.250
LATE BS	-24.558	7.250	-32.792	-11.820
INITIAL DS	-29.639	8.510	-40.326	-11.610
IMPACT	21.975	7.220	8.041	50.100
EARLY FT	19.885	9.860	-7.697	40.070
FINISH	16.353	10.460	-9.881	34.670

Appendix Table 11: Descriptive analysis of the right hip angles

3.2 Left hip angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION-EXTENSION (-) Flexion (+) Extension				
ADDRESS	-40.382	7.150	-52.274	-29.060
EARLYBS	-34.808	8.160	-49.885	-22.870
LATE BS	-32.661	9.600	-50.800	-18.790
INITIAL DS	-33.214	10.340	-52.506	-14.770
IMPACT	-19.389	5.470	-32.265	-9.330
EARLY FT	-12.297	5.030	-21.992	-3.470
FINISH	-10.281	5.160	-19.162	1.100
ADDUCTION-ABDUCTION (-) Adduction (+) Abduction				
ADDRESS	5.625	2.450	0.653	10.330
EARLY BS	15.907	4.550	6.109	26.470
LATE BS	20.657	4.240	10.289	29.320
INITIAL DS	23.440	4.020	14.701	31.740
IMPACT	-13.606	4.990	-26.441	-4.090
EARLY FT	-17.694	4.010	-27.473	-9.790
FINISH	-22.390	2.840	-29.254	-17.580
ROTATION (+) External (-) Internal				
ADDRESS	6.246	8.660	-12.077	20.130
EARLY BS	27.115	10.510	0.952	39.170
LATE BS	34.446	10.530	9.564	49.470
INITIAL DS	37.100	8.960	23.975	51.090
IMPACT	-8.321	8.270	-29.892	5.090
EARLY FT	0.019	8.560	-16.885	18.430
FINISH	-25.184	6.530	-38.448	-10.760

Appendix Table 12: Descriptive analysis of the left hip angles

3.3 Hip angular velocity

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
RIGHT				
ADDRESS	33.151	20.890	6.533	90.434
EARLYBS	69.899	22.110	28.766	115.269
LATE BS	61.446	22.760	23.980	107.942
INITIAL DS	64.232	34.110	15.313	178.394
IMPACT	417.875	79.710	260.289	600.706
EARLY FT	186.334	73.270	56.566	355.257
FINISH	40.874	34.630	7.764	158.802
LEFT				
ADDRESS	27.252	14.910	4.357	67.815
EARLY BS	91.447	26.890	31.315	192.870
LATE BS	55.440	29.320	11.967	203.422
INITIAL DS	94.393	51.240	13.369	213.598
IMPACT	348.053	78.470	203.602	676.096
EARLY FT	181.596	111.790	39.741	477.789
FINISH	33.922	25.090	7.018	135.426

Appendix Table 13: Descriptive analysis of the hip angular velocity

3.4 Right hip torques

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
X_component				
ADDRESS	-0.977093	0.3393	-158.483	-0.33300
EARLY BS	-1.385.462	0.6202	-259.190	-0.40563
LATE BS	-1.354.807	0.5630	-253.697	-0.44829
INITIAL DS	-1.031.529	0.4012	-213.059	-0.50317
IMPACT	-0.248630	0.5550	-129.088	102.982
EARLY FT	0.189816	0.3870	-0.76164	102.804
FINISH	0.016642	0.6811	-174.948	111.508
Y_component				
ADDRESS	-0.091242	0.1447	-0.42396	0.14245
EARLY BS	0.243430	0.3044	-0.15149	0.89350
LATE BS	0.389969	0.3445	-0.15198	115.140
INITIAL DS	0.255006	0.2744	-0.17868	0.90169
IMPACT	-0.837705	0.3466	-138.841	-0.01764
EARLY FT	-0.891734	0.4662	-182.332	-0.16103
FINISH	-0.484234	0.4748	-317.925	0.12377
Z_component				
ADDRESS	-0.080902	0.0970	-0.31852	0.10373
EARLY BS	-0.108495	0.1316	-0.40821	0.06502
LATE BS	-0.113083	0.1305	-0.40379	0.18865
INITIAL DS	-0.191014	0.1883	-0.56364	0.14455
IMPACT	0.283693	0.2067	-0.11066	0.65950
EARLY FT	0.253540	0.2141	-0.15917	0.66998
FINISH	-0.020453	0.2323	-0.44658	0.95710

Appendix Table 14: Descriptive analysis of the right hip articular torques

3.4 Left hip torques

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
X_component				
ADDRESS	-0.881768	0.1967	-135.748	-0.56808
EARLY BS	-0.389130	0.2398	-0.95216	0.09126
LATE BS	-0.384498	0.2613	-106.119	-0.01931
INITIAL DS	-0.772613	0.2975	-136.314	-0.25085
IMPACT	0.004237	0.3236	-101.742	0.39103
EARLY FT	-0.010772	0.5049	-173.789	0.51209
FINISH	0.078402	10.203	-181.420	254.293
Y_component				
ADDRESS	-0.016994	0.1008	-0.20790	0.14501
EARLY BS	-0.146789	0.0545	-0.23064	-0.00491
LATE BS	-0.167628	0.1099	-0.35060	0.07814
INITIAL DS	-0.220296	0.3290	-0.66643	0.75740
IMPACT	0.200608	0.5635	-0.26041	216.858
EARLY FT	0.099395	0.4276	-0.25135	135.217
FINISH	0.403716	0.5353	-0.60893	146.255
Z_component				
ADDRESS	-0.296961	0.0928	-0.53558	-0.16507
EARLY BS	-0.097639	0.0715	-0.24418	0.04293
LATE BS	-0.010732	0.0518	-0.14456	0.10940
INITIAL DS	0.085592	0.1133	-0.24058	0.25242
IMPACT	-0.158772	0.3212	-138.668	0.19005
EARLY FT	-0.151973	0.2877	-109.744	0.07875
FINISH	-0.209549	0.2785	-0.77071	0.44203

Appendix Table 15: Descriptive analysis of the left hip articular torques

4. Pelvis

4.1 Pelvis angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION-EXTENSION (-) Flexion (+) Extension				
ADDRESS	-20.434	5.240	-28.185	-9.020
EARLYBS	-19.065	3.910	-26.021	-11.527
LATE BS	-19.855	3.990	-26.662	-13.216
INITIAL DS	-21.944	5.200	-31.727	-13.040
IMPACT	-1.832	4.410	-9.012	8.912
EARLY FT	2.095	5.930	-8.629	17.402
FINISH	-4.791	9.730	-20.231	20.866
LATERAL FLEXION (+) Right (-) Left				
ADDRESS	-0.206	2.070	-4.777	4.430
EARLY BS	2.496	3.590	-7.534	8.284
LATE BS	2.218	5.170	-10.475	9.820
INITIAL DS	1.537	6.630	-14.311	11.438
IMPACT	5.247	7.350	-9.478	19.559
EARLY FT	6.335	8.430	-11.321	22.741
FINISH	-14.109	19.050	-72.849	10.327
ROTATION (+) Right (-) Left				
ADDRESS	-1.426	3.340	-12.265	3.070
EARLY BS	29.773	7.300	17.462	43.622
LATE BS	43.870	7.930	30.144	56.401
INITIAL DS	52.414	5.520	39.850	62.318
IMPACT	-45.461	10.580	-61.419	-17.183
EARLY FT	-56.685	10.310	-81.405	-39.596
FINISH	-116.803	14.780	-138.662	-78.968

Appendix Table 16: Descriptive analysis of the pelvis angles

4.2 Pelvis angular velocity

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
ADDRESS	-20.442	11.950	-50.194	1.101
EARLYBS	-108.468	22.570	-152.003	-63.170
LATE BS	-77.883	21.350	-121.545	-31.184
INITIAL DS	86.306	70.140	5.062	225.463
IMPACT	322.537	91.520	171.993	667.404
EARLY FT	36.680	132.450	-219.255	314.310
FINISH	32.307	69.990	-42.360	328.090

Appendix Table 17: Descriptive analysis of the pelvis angular velocity

5. Trunk

5.1 Trunk angles

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
FLEXION -EXTENSION (+) Flexion (-) Estension				
ADDRESS	14.484	8.460	-7.526	27.642
EARLYBS	13.589	9.950	-11.624	26.349
LATE BS	10.461	9.470	-12.272	22.569
INITIALDS	5.504	10.660	-17.167	20.002
IMPACT	22.008	7.830	0.827	31.486
EARLY FT	15.372	5.330	4.889	24.146
FINISH	-17.812	10.310	-32.409	1.594
LATERAL INCLINATION (+) Right (-)Left				
ADDRESS	4.535	3.800	-7.038	8.643
EARLY BS	-4.828	3.040	-11.759	0.555
LATE BS	-7.294	5.050	-14.179	6.022
INITIAL DS	-10.292	6.590	-18.618	7.068
IMPACT	13.906	9.020	-9.681	25.675
EARLY FT	23.188	8.130	0.021	34.513
FINISH	11.817	8.920	-6.051	34.547
ROTATION (-) Right (+) Left				
ADDRESS	8.388	4.380	-0.519	14.776
EARLY BS	-20.530	5.630	-29.240	-5.191
LATE BS	-38.289	6.530	-48.677	-23.016
INITIAL DS	-56.270	6.440	-66.282	-44.291
IMPACT	-29.858	11.450	-55.270	-7.653
EARLY FT	-12.243	7.550	-29.276	1.912
FINISH	49.319	5.600	41.036	62.808

Appendix Table 18: Descriptive analysis of the trunk angles

5.2 Trunk angular velocity

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
ADDRESS	1.507	10.600	-21.307	18.987
EARLYBS	-139.095	48.670	-288.257	-49.860
LATE BS	-103.522	28.930	-187.508	-64.656
INITIALDS	-56.784	37.510	-123.416	27.203
IMPACT	239.177	70.640	-5.920	399.190
EARLY FT	470.783	186.760	31.254	709.724
FINISH	9,06	8,91	0,486	46,68

Appendix Table 19: Descriptive analysis of the trunk angular velocity

6. Head

6.1 Head angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION - EXTENSION (+) Flexion (-) Extension				
ADDRESS	-8.123	12.236	-31.589	12.850
EARLYBS	-5.792	11.925	-35.155	13.720
LATE BS	-1.896	12.416	-31.734	23.450
INITIALDS	1.263	15.656	-36.922	30.320
IMPACT	-24.682	16.229	-53.469	15.670
EARLY FT	-30.478	14.632	-59.216	4.530
FINISH	-3.245	11.803	-30.504	19.400
LATERAL INCLINATION (+) Right (-) Left				
ADDRESS	0.264	5.842	-15.815	12.480
EARLY BS	13.783	6.403	3.331	27.430
LATE BS	18.165	7.826	7.458	36.170
INITIAL DS	15.195	10.102	-6.773	32.040
IMPACT	-8.301	7.156	-25.461	7.740
EARLY FT	-13.636	11.372	-45.311	4.820
FINISH	-7.138	14.234	-31.013	29.060
ROTATION (-) Right (+) Left				
ADDRESS	-14.014	7.869	-36.920	-1.270
EARLY BS	39.712	10.204	16.460	53.030
LATE BS	68.644	8.535	52.707	83.630
INITIAL DS	86.685	7.745	75.274	101.100
IMPACT	-20.447	14.087	-44.351	12.450
EARLY FT	-43.973	9.279	-60.909	-20.300
FINISH	-75.364	8.339	-87.664	-51.870

Appendix Table 20: Descriptive analysis of the head angles

6.2 Head angular velocity

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
ADDRESS	0.450	0.338	0.148	1.890
EARLYBS	4.285	1.129	2.797	7.780
LATE BS	2.758	0.745	1.321	4.630
INITIALDS	1.102	0.411	0.492	2.120
IMPACT	11.177	1.630	7.298	13.810
EARLY FT	6.439	2.179	1.278	9.870
FINISH	0.80	0.99	0.14	5.01

Appendix Table 21: Descriptive analysis of the head angular velocity

7. Shoulders

7.1 Right shoulder angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION - EXTENSION (+) Flexion (-) Extension				
ADDRESS	16.56	4.39	6.83	23.89
EARLYBS	21.17	4.79	11.05	29.68
LATE BS	42.09	8.31	30.51	64.06
INITIALDS	72.03	12.41	51.45	94.04
IMPACT	27.81	8.74	10.98	48.06
EARLY FT	56.84	4.31	43.41	64.47
FINISH	105.4	8.08	88.53	122.84
PRONATION – SUPINATION (+) Pronation (-) Supination				
ADDRESS	94.02	10.5	66.82	107.93
EARLY BS	85.04	13.28	49.71	101.08
LATE BS	78	11.26	50.67	95.26
INITIAL DS	46.93	16.4	6.97	73.9
IMPACT	81.16	14.98	44.08	100.13
EARLY FT	95.28	9.86	75.38	110.17
FINISH	127.28	10.78	110.63	144.17

Appendix Table 22: Descriptive analysis of the right shoulder angles

7.2 Left shoulder angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION - EXTENSION (-) Flexion (+) Extension				
ADDRESS	7.88	3.79	2.96	15.21
EARLYBS	40.89	8.51	27.14	56.76
LATE BS	72.66	5.13	62.97	85.32
INITIALDS	108.43	7.9	98.4	125.64
IMPACT	13.75	4.36	5.12	21.4
EARLY FT	33.03	8.43	21.64	51.09
FINISH	76.91	14.9	51.47	103.57
PRONATION – SUPINATION (-) Pronation (+) Supination				
ADDRESS	-110.29	7.27	-122.02	-96.68
EARLY BS	-110.05	8.3	-121.78	-92.18
LATE BS	-113.01	9.03	-129.46	-97.17
INITIAL DS	-130.86	9.09	-149.1	-114.08
IMPACT	-103.68	8.74	-118.11	-88.91
EARLY FT	-103.7	8.6	-117.3	-90.63
FINISH	-21.06	19.52	-86.32	8.56

Appendix Table 23: Descriptive analysis of the left shoulder angles

7.3 Shoulders angular velocities

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
RIGHT				
ADDRESS	-0.484	7.32	-15.84	18.32
EARLYBS	-20.006	48.91	-115.07	88.21
LATE BS	-58.962	50.54	-145.37	62.57
INITIALDS	-22.777	36.66	-85.15	46.45
IMPACT	98.504	164.23	-160.75	527.89
EARLY FT	227.864	268.45	-384.49	661.53
FINISH	-21.383	85.96	-237.11	366.00
LEFT				
ADDRESS	1.963	10.43	-26.86	23.78
EARLY BS	-27.448	92.57	-247.45	108.79
LATE BS	-102.139	78.29	-269.02	21.46
INITIAL DS	-26.48	52.20	-137.51	92.08
IMPACT	151.172	110.41	-102.05	315.28
EARLY FT	86.588	161.12	-170.85	478.48
FINISH	44.393	88.87	-38.00	354.29

Appendix Table 24: Descriptive analysis of the shoulders angular velocity

8. Elbows

8.1 Right elbow angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION - EXTENSION (+) Flexion (-) Extension				
ADDRESS	2.344	9.16	-8.50	27.31
EARLYBS	22.077	11.51	-0.69	40.155
LATE BS	48.868	12.52	25.66	70.897
INITIALDS	77.292	17.24	30.08	104.261
IMPACT	29.688	13.18	-3.08	46.73
EARLY FT	-10.548	6.60	-35.63	-0.712
FINISH	43.433	37.80	-72.70	88.239
PRONATION – SUPINATION (+) Pronation (-) Supination				
ADDRESS	6.312	14.50	-21.34	31.009
EARLY BS	24.557	14.15	-5.98	45.596
LATE BS	25.318	12.70	1.84	42.03
INITIAL DS	11.576	19.24	-19.48	45,495
IMPACT	12.285	19.25	-14.00	53.16
EARLY FT	-37.778	19.80	-86.39	-8,024
FINISH	-60.698	17.85	-98.17	18.145

Appendix Table 25: Descriptive analysis of the right elbow angles

8.2 Left elbow angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION - EXTENSION (+) Flexion (-) Extension				
ADDRESS	-8.958	3.66	-16.74	-1.909
EARLYBS	-9.76	7.32	-32.06	-1.002
LATE BS	-5,204	17.37	-59.00	12.52
INITIALDS	3.473	27.81	-78.53	36.891
IMPACT	-0.933	14.89	-43.72	20.827
EARLY FT	10.948	16.83	-9.92	59.581
FINISH	84.837	41.34	-45.44	119.752
PRONATION – SUPINATION (+) Pronation (-) Supination				
ADDRESS	-21.093	18.54	-67.86	2,18
EARLY BS	-49.471	17.52	-93.76	-27.808
LATE BS	-69.014	13.57	-93.75	-42.746
INITIAL DS	-77.058	14.31	-104.54	-43.441
IMPACT	-42.856	21.68	-81.30	12.31
EARLY FT	31.984	15.37	-11.17	59.581
FINISH	-25.445	18.87	-45.44	26.436

Appendix Table 26: Descriptive analysis of the left elbow angles

8.3 Elbow angular velocities

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
RIGHT				
ADDRESS	41.06	38.80	5.52	188.16
EARLYBS	197.00	50.41	91.92	315.44
LATE BS	258.24	59.76	190.66	465.21
INITIALDS	97.08	42.62	35.32	263.67
IMPACT	844.25	169.84	484.53	1452.92
EARLY FT	865.74	355.91	141.36	2024.78
FINISH	90.50	67.62	2.06	240.25
LEFT				
ADDRESS	55.75	44.89	3.70	171.24
EARLY BS	182.19	59.15	86.44	336.78
LATE BS	135.95	65.57	12.17	419.17
INITIAL DS	69.16	46.97	19.69	265.14
IMPACT	1052.62	198.60	504.90	1566.29
EARLY FT	886.42	357.66	199.78	1880.23
FINISH	137.29	128.21	13.17	634.07

Appendix Table 27: Descriptive analysis of the elbows angular velocity

9. Hands

9.1 Right hand angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION - EXTENSION (+) Flexion (-) Extension				
ADDRESS	-11.294	5.87	-24.85	-0.361
EARLYBS	-31.082	14.74	-54.12	8.33
LATE BS	-49.342	47.53	-88.85	157.748
INITIALDS	-85.758	18.29	-111.53	-52.987
IMPACT	-39.942	12.59	-59.77	-12.838
EARLY FT	13.86	9.21	-7.67	35.885
FINISH	-98.89	15.32	-129.04	-63.189
DEVIATION (-) Radial (+) Ulnar				
ADDRESS	-26.231	4.54	-36.16	-19.983
EARLY BS	-24.553	16.52	-86.23	23.201
LATE BS	0.568	42.12	-53.68	143.018
INITIAL DS	-15.938	17.68	-62.70	11.555
IMPACT	-44.245	12.45	-67.18	-21.391
EARLY FT	-23.62	12.96	-44.07	9.42
FINISH	18.6	28.63	-64.40	60.559

Appendix Table 28: Descriptive analysis of the right hand angles

9.2 Left hand angles

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
FLEXION - EXTENSION (-)Flexion (+) Extension				
ADDRESS	-10.45	8.25	-22.25	7,745
EARLYBS	-3.81	18.58	-36.05	54.333
LATE BS	-29.77	40.50	-146.90	35,349
INITIALDS	-44.94	17.23	-74.93	-11.897
IMPACT	13.98	10.26	-8.96	31.373
EARLY FT	-34.08	17.26	-73.58	-0.227
FINISH	-66.25	11.47	-92.19	-46,41
DEVIATION (-) Radial (+) Ulnar				
ADDRESS	-27.12	5.90	-41.06	-18,959
EARLY BS	-18.50	19.12	-83.11	5.266
LATE BS	-1.49	44.89	-158.82	56.431
INITIAL DS	33.50	15.39	6.21	56,264
IMPACT	-14.01	10.18	-37.54	3.128
EARLY FT	-18.41	10.37	-44.81	2,116
FINISH	7.38	11.75	-27.24	31.59

Appendix Table 29: Descriptive analysis of the left hand angles

9.3 Hands angular velocities

Position	MEAN	STD	MIN	MAX
	(º/s)	(º/s)	(º/s)	(º/s)
RIGHT				
ADDRESS	47.95	50.87	5.92	244.78
EARLYBS	201.02	91.37	86.53	468.96
LATE BS	273.57	158.56	113.55	838.60
INITIALDS	64.05	33.48	18.65	144.64
IMPACT	1601.52	187.81	1297.54	2010.43
EARLY FT	949.38	184.10	690.68	1605.82
FINISH	127.44	127.61	13.21	636.84
LEFT				
ADDRESS	72.07	51.89	8.64	218.38
EARLY BS	205.79	123.63	71.19	712.26
LATE BS	323.91	151.87	119.53	738.59
INITIAL DS	91.62	68.56	11.27	366.32
IMPACT	1147.12	148.08	756.49	1404.54
EARLY FT	1170.59	204.43	794.97	1647.87
FINISH	77.88	53.19	13.64	243.54

Appendix Table 30: Descriptive analysis of the hands angular velocity

10. X Factor

	Mean	St. Deviation	Minimum	Maximum
X_FACTOR_top	61.529	70.016	48.985	77.351
X_FACTOR_stretch_rel	4.488	28.228	0.000	11.337
X_FACTOR_mid_impact	30.069	88.697	15.167	51.304

Appendix Table 31: Descriptive analysis of the X factor at the top position, the stretch position and at mid impact

11. Time

	Mean	St. Deviation	Minimum	Maximum
t_swing_s	1.638	0.2083	1.324	2.296
t_backswing_s	0.800	0.1165	0.616	1.124
t_downswing_s	0.266	0.0305	0.208	0.316

Appendix Table 32:Descriptive analysis of the time of total swing, backswing and downswing

12. Ground Reaction Forces

12.1 Right GRF

Position	MEAN	STD	MIN	MAX
	(N)	(N)	(N)	(N)
X_component				
ADDRES	14.88	11.53	1.20	58.57
EARLY BS	6.91	16.92	-28.73	42.83
LATE BS	-11.91	20.31	-51.79	32.24
INITIAL DS	-71.17	30.17	-123.53	-10.49
IMPACT	-25.26	20.33	-59.49	10.13
EARLY FT	6.78	35.57	-76.59	61.65
FINISH	12.35	17.52	-15.64	74.56
Y_component				
ADDRESS	-44.96	10.86	-74.43	-26.67
EARLY BS	-64.89	15.66	-95.53	-26.38
LATE BS	-57.46	14.68	-89.44	-25.15
INITIAL DS	-52.86	22.86	-105.54	-21.07
IMPACT	-47.93	29.86	-127.35	-11.05
EARLY FT	-36.18	55.70	-100.82	98.07
FINISH	6.09	27.67	-42.33	84.34
Z_component				
ADDRESS	380.56	82.89	268.73	607.90
EARLY BS	611.24	125.17	442.66	823.72
LATE BS	565.53	110.64	386.42	741.58
INITIAL DS	402.34	86.50	252.78	527.49
IMPACT	452.28	98.97	263.96	738.82
EARLY FT	452.32	148.05	191.54	746.65
FINISH	194.33	61.84	97.06	370.51

Appendix Table 33: Ground Reaction Forces calculated for the right foot during the different phases of the swing

12.2 Left GRF

Position	MEAN	STD	MIN	MAX
	(N)	(N)	(N)	(N)
X_component				
ADDRES	-14.14	7.08	-32.85	-3.86
EARLY BS	-19.69	8.94	-37.37	-1.25
LATE BS	3.55	13.23	-19.13	26.75
INITIAL DS	55.66	35.02	-14.49	115.10
IMPACT	-27.09	24.19	-80.68	21.09
EARLY FT	-29.51	23.98	-82.47	31.73
FINISH	-16.88	17.70	-80.91	12.74
Y_component				
ADDRESS	71.67	10.07	57.84	95.40
EARLY BS	35.10	17.48	4.57	74.84
LATE BS	21.54	16.57	-3.79	53.78
INITIAL DS	-16.39	22.56	-54.72	30.41
IMPACT	21.18	45.00	-88.98	91.36
EARLY FT	3.66	35.46	-63.80	69.74
FINISH	15.47	32.18	-76.58	66.82
Z_component				
ADDRESS	383.22	50.34	282.58	465.36
EARLY BS	176.79	59.06	46.60	287.77
LATE BS	166.16	53.75	77.08	286.97
INITIAL DS	259.70	46.42	182.15	382.59
IMPACT	203.77	178.52	23.49	736.75
EARLY FT	225.15	183.35	9.02	722.15
FINISH	539.20	123.74	183.69	725.67

Appendix Table 34: Ground Reaction Forces calculated for the left foot during the different phases of the swing

13. Ground Reaction Torques

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
ADDRESS	-1.49	1.90	-6.28	1.612
EARLYBS	8.32	5.51	-1.75	19.963
LATE BS	12.60	5.67	0.51	23.002
INITIAL DS	12.55	5.98	4.05	24.518
IMPACT	-6.88	4.90	-20.36	0.514
EARLY FT	-7.66	6.12	-20.62	1.605
FINISH	-12.40	4.64	-20.90	-2.022

Appendix Table 35: Ground Reaction Torques calculated summing the Z-components of the two feet

14. COP displacement

Position	MEAN	STD	MIN	MAX
	(º)	(º)	(º)	(º)
X_component				
ADDRES	0.409	0.0337	0.353	0.470
EARLY BS	0.408	0.0435	0.329	0.484
LATE BS	0.419	0.0468	0.348	0.501
INITIAL DS	0.408	0.0426	0.314	0.487
IMPACT	0.334	0.0574	0.213	0.441
EARLY FT	0.332	0.0499	0.226	0.448
FINISH	0.397	0.0375	0.333	0.495
Y_component				
ADDRESS	0.396	0.0409	0.306	0.469
EARLY BS	0.550	0.0451	0.458	0.658
LATE BS	0.549	0.0385	0.482	0.637
INITIAL DS	0.467	0.0383	0.369	0.529
IMPACT	0.523	0.0979	0.307	0.677
EARLY FT	0.506	0.0870	0.322	0.662
FINISH	0.286	0.0568	0.165	0.423

Appendix Table 36: COP displacements during the different phases of swing

APPENDIX II - Anthropometrical descriptive analysis

1. Anthropometrical characteristics of the sample

	MEAN	STD	MIN	MAX
Crotch_height_cm	77.85	4.930	69.00	85.50
Knee_height_cm	48.47	2.710	43.80	51.60
Bust_chest_girth_horizontal_cm	101.15	4.332	95.10	110.00
Arm_length_left_cm	64.14	3.545	59.80	71.20
Arm_length_right_cm	64.23	4.083	57.00	70.70
Upper_arm_length_left_cm_	35.22	2.960	31.10	40.50
Upper_arm_length_right_cm	35.83	1.866	34.20	39.20
Forearm_length_left_cm	28.91	1.357	26.30	30.70
Forearm_length_right_cm	28.40	2.567	22.30	31.60
Upper_arm_girth_left_cm	31.12	2.050	27.50	34.50
Upper_arm_girth_right_cm	31.04	1.660	28.30	33.90
Forearm_girth_lef_cm	27.52	1.363	24.60	29.00
Forearm_girth_right_cm	27.99	1.422	25.30	29.80
Thigh_girth_left_hor_cm	56.86	3.159	51.10	61.90
Thigh_girth_right_hor_cm	57.18	2.820	51.10	61.30
Calf_girth_left_cm	37.61	3.023	31.80	43.00
Calf_girth_right_cm	37.48	2.842	32.00	42.80
Trochanter_belt_height_cm	34.09	1.765	30.60	37.20
Biacromial_diameter_cm	41.11	1.995	38.10	45.10
Hand_length_right_cm	18.18	1.103	16.50	19.40
Thigh_length_right_cm	42.79	2.628	38.40	47.00
Thigh_length_left_cm	42.80	3.171	37.30	48.00
Hand_palm_length_right_cm	9.82	0.781	8.80	10.80
Hand_palm_length_left_cm	42.96	2.472	39.60	46.20
Leg_length_right_cm	42.73	2.376	39.50	46.60
Ulnar_styloid_height_left_cm	84.50	4.090	78.90	90.90
Trochanter_average_height_cm	90.96	5.326	82.60	97.80
Trochanter_height_right_cm	90.84	5.055	82.90	97.40
Trochanter_height_left_cm	91.08	5.642	82.30	98.20
Hand_width_right_cm	9.03	0.485	8.20	10.00
Foot_length_cm	26.95	4.536	17.70	36.50

Appendix Table 37: Descriptive Analysis of the Anthropometrical Data

2. Characteristics of the somatotypes of the sample

Subject	Ectomorphy	Mesomorphy	Endomorphy
1	3.2	5.3	2.2
2	0.7	3.5	3.9
3	0.1	4.9	4.1
4	2.8	4.2	5
5	3.1	4.5	2.8
6	1.4	4.2	5.8
7	3.3	3.6	2.5
8	3	4.7	3.5
9	1.7	4.9	5.1
10	2.9	4.2	2.6

Appendix Table 38: Somatotype's values of each subject

APPENDIX III - Correlations

1. Correlation between biomechanical parameters and performing parameters

1.1 Ankle

1.1.1 Right Ankle Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	0.100	0.280	0.432
	p-value	0.469	0.0386	0.002
EARLY BS	correlation	0.002	0.040	0.133
	p-value	0.988	0.771	0.357
LATE BS	correlation	0.002	0.040	0.104
	p-value	0.988	0.771	0.471
INITIAL DS	correlation	-0.336	-0.108	-0.144
	p-value	0.0121	0.432	0.319
IMPACT	correlation	0.049	0.009	-0.376
	p-value	0.724	0.95	0.007
EARLY FT	correlation	-0.008	-0.184	-0.269
	p-value	0.955	0.179	0.059
FINISH	correlation	0.177	0.179	0.083
	p-value	0.197	0.192	0.567
ABDUCTION -ADDUCTION				
ADDRESS	correlation	-0.523	-0.365	-0.020
	p-value	0.001	0.0061	0.893
EARLY BS	correlation	-0.557	-0.346	-0.227
	p-value	0.001	0.00973	0.113
LATE BS	correlation	-0.516	-0.339	-0.212
	p-value	0.001	0.0113	0.14
INITIAL DS	correlation	-0.314	-0.257	-0.167
	p-value	0.0197	0.0585	0.246
IMPACT	correlation	-0.333	-0.090	0.164
	p-value	0.013	0.513	0.255
EARLY FT	correlation	-0.443	-0.415	0.179
	p-value	0.001	0.00164	0.214
FINISH	correlation	-0.327	-0.512	0.413
	p-value	0.0148	0.001	0.0029

EXTERNAL – INTERNAL ROTATION				
ADDRESS	correlation	-0.414	-0.320	0.070
	p-value	0.00167	0.0173	0.629
EARLY BS	correlation	-0.182	-0.061	0.025
	p-value	0.185	0.66	0.863
LATE BS	correlation	-0.069	0.017	0.043
	p-value	0.616	0.899	0.766
INITIAL DS	correlation	0.067	0.079	0.193
	p-value	0.629	0.567	0.18
IMPACT	correlation	-0.115	-0.156	0.031
	p-value	0.405	0.255	0.833
EARLY FT	correlation	-0.029	-0.190	0.014
	p-value	0.836	0.166	0.923
FINISH	correlation	-0.067	-0.262	-0.397
	p-value	0.627	0.0538	0.00434

Appendix Table 39: Correlations between Right Ankle Angle and Performing Factors

1.1.2 Left Ankle Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.163	0.040	-0.103
	p-value	0.235	0.771	0.477
EARLY BS	correlation	-0.278	-0.233	-0.364
	p-value	0.0398	0.0873	0.00945
LATE BS	correlation	-0.434	-0.269	-0.312
	p-value	0.001	0.0473	0.0272
INITIAL DS	correlation	-0.342	-0.124	-0.289
	p-value	0.0107	0.367	0.0414
IMPACT	correlation	-0.210	0.127	-0.034
	p-value	0.124	0.355	0.817
EARLY FT	correlation	-0.208	0.004	0.082
	p-value	0.127	0.977	0.572
FINISH	correlation	-0.400	-0.047	0.103
	p-value	0.00249	0.735	0.476
ABDUCTION -ADDUCTION				
ADDRESS	correlation	0.332	0.033	-0.182
	p-value	0.0132	0.814	0.205
EARLY BS	correlation	0.097	-0.149	-0.204
	p-value	0.48	0.276	0.155
LATE BS	correlation	-0.022	-0.145	0.022
	p-value	0.875	0.292	0.881
INITIAL DS	correlation	0.034	0.020	0.076

	p-value	0.807	0.886	0.599
IMPACT	correlation	0.114	-0.197	-0.542
	p-value	0.408	0.15	<0.001
EARLY FT	correlation	0.192	-0.166	-0.474
	p-value	0.16	0.225	<0.001
FINISH	correlation	-0.088	-0.421	-0.118
	p-value	0.523	0.00138	0.414
EXTERNAL – INTERNAL ROTATION				
ADDRESS	correlation	-0.155	-0.130	0.525
	p-value	0.258	0.345	<0.001
EARLY BS	correlation	-0.011	0.021	0.628
	p-value	0.937	0.881	<0.001
LATE BS	correlation	0.078	0.045	0.634
	p-value	0.573	0.742	<0.001
INITIAL DS	correlation	0.042	0.048	0.585
	p-value	0.761	0.728	<0.001
IMPACT	correlation	-0.247	-0.275	0.223
	p-value	0.0692	0.0423	0.12
EARLY FT	correlation	-0.250	-0.284	0.336
	p-value	0.0661	0.0354	0.0172
FINISH	correlation	-0.084	-0.055	0.522
	p-value	0.544	0.691	<0.001

Appendix Table 40: Correlations between Left Ankle Angle and Performing Factors

1.1.3 Ankle Angular Velocity

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
RIGHT				
ADDRESS	correlation	0.060	0.152	0.044
	p-value	0.662	0.266	0.76
EARLY BS	correlation	0.256	0.379	0.060
	p-value	0.0591	0.00427	0.681
LATE BS	correlation	-0.027	0.138	0.265
	p-value	0.845	0.315	0.0626
INITIAL DS	correlation	-0.028	0.200	-0.192
	p-value	0.839	0.143	0.181
IMPACT	correlation	0.295	0.541	-0.168
	p-value	0.0288	0.001	0.244
EARLY FT	correlation	0.304	0.432	-0.084
	p-value	0.0242	0.001	0.564
FINISH	correlation	0.162	0.120	-0.185
	p-value	0.237	0.384	0.199

LEFT				
ADDRESS	correlation	0.213	0.063	0.346
	p-value	0.119	0.645	0.0139
EARLY BS	correlation	0.147	0.101	0.062
	p-value	0.284	0.461	0.667
LATE BS	correlation	0.273	0.255	-0.103
	p-value	0.0435	0.0599	0.475
INITIAL DS	correlation	0.247	-0.083	-0.077
	p-value	0.0692	0.547	0.593
IMPACT	correlation	0.150	0.026	-0.381
	p-value	0.275	0.849	0.00626
EARLY FT	correlation	0.268	-0.100	-0.069
	p-value	0.0476	0.466	0.632
FINISH	correlation	0.405	0.129	0.053
	p-value	0.00215	0.349	0.714

Appendix Table 41: Correlations between Ankle Angular Velocity and Performing Factors

1.1.4 Right Ankle Torque

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
X_component				
ADDRESS	correlation	-0.643	-0.666	0.318
	p-value	<0.001	<0.001	0.0246
EARLY BS	correlation	-0.132	0.101	0.257
	p-value	0.362	0.485	0.0716
LATE BS	correlation	-0.226	0.133	0.064
	p-value	0.115	0.357	0.657
INITIAL DS	correlation	-0.182	0.034	-0.009
	p-value	0.207	0.812	0.951
IMPACT	correlation	0.317	0.294	0.599
	p-value	0.0248	0.0382	<0.001
EARLY FT	correlation	0.133	0.449	0.451
	p-value	0.356	0.00107	0.00102
FINISH	correlation	0.289	0.249	0.318
	p-value	0.0418	0.0814	0.0244
Y_component				
ADDRESS	correlation	-0.493	-0.408	0.023
	p-value	<0.001	0.00323	0.876
EARLY BS	correlation	0.057	0.362	0.092
	p-value	0.692	0.00969	0.527
LATE BS	correlation	-0.299	0.118	0.071
	p-value	0.0348	0.415	0.626
INITIAL DS	correlation	-0.414	-0.180	-0.266

	p-value	0.00281	0.212	0.0619
IMPACT	correlation	-0.182	-0.170	0.103
	p-value	0.207	0.239	0.475
EARLY FT	correlation	0.174	0.419	0.092
	p-value	0.228	0.00247	0.524
FINISH	correlation	0.040	0.178	0.069
	p-value	0.784	0.215	0.632
Z_component				
ADDRESS	correlation	-0.620	-0.494	0.402
	p-value	<0.001	<0.001	0.00378
EARLY BS	correlation	-0.360	0.017	0.129
	p-value	0.0102	0.909	0.371
LATE BS	correlation	-0.411	-0.064	-0.078
	p-value	0.00301	0.661	0.591
INITIAL DS	correlation	-0.207	-0.016	-0.237
	p-value	0.15	0.912	0.0973
IMPACT	correlation	-0.084	-0.440	0.249
	p-value	0.56	0.00137	0.0818
EARLY FT	correlation	0.435	0.430	0.383
	p-value	0.00159	0.00182	0.00611
FINISH	correlation	0.214	0.197	0.030
	p-value	0.136	0.171	0.837

Appendix Table 42: Correlations between Right Ankle Torques and Performing Factors

1.1.5 Left Ankle Torque

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
X_component				
ADDRESS	correlation	-0.320	-0.395	-0.221
	p-value	0.0234	0.00454	0.122
EARLY BS	correlation	0.159	0.109	0.277
	p-value	0.271	0.451	0.0512
LATE BS	correlation	0.153	-0.019	0.475
	p-value	0.287	0.898	<0.001
INITIAL DS	correlation	0.336	0.005	-0.159
	p-value	0.0169	0.972	0.27
IMPACT	correlation	0.171	-0.150	0.592
	p-value	0.236	0.299	<0.001
EARLY FT	correlation	0.219	0.091	0.359
	p-value	0.126	0.532	0.0106
FINISH	correlation	0.134	-0.197	-0.162
	p-value	0.353	0.171	0.262

Y_component				
ADDRESS	correlation	0.288	0.164	0.165
	p-value	0.0427	0.254	0.251
EARLY BS	correlation	0.078	0.088	0.368
	p-value	0.592	0.544	0.00854
LATE BS	correlation	0.148	0.052	0.545
	p-value	0.304	0.717	<0.001
INITIAL DS	correlation	0.381	0.542	0.048
	p-value	0.00632	<0.001	0.741
IMPACT	correlation	0.140	0.056	0.114
	p-value	0.333	0.698	0.429
EARLY FT	correlation	-0.202	-0.186	-0.212
	p-value	0.159	0.196	0.14
FINISH	correlation	-0.205	0.084	-0.351
	p-value	0.153	0.563	0.0125
Z_component				
ADDRESS	correlation	0.034	0.051	-0.277
	p-value	0.817	0.727	0.0512
EARLY BS	correlation	0.312	0.321	0.356
	p-value	0.0276	0.023	0.0111
LATE BS	correlation	0.297	0.185	0.456
	p-value	0.0363	0.197	<0.001
INITIAL DS	correlation	-0.140	0.260	0.091
	p-value	0.332	0.0679	0.528
IMPACT	correlation	0.446	0.490	0.354
	p-value	0.00119	<0.001	0.0116
EARLY FT	correlation	-0.227	-0.186	0.195
	p-value	0.113	0.196	0.174
FINISH	correlation	-0.063	0.082	-0.288
	p-value	0.664	0.569	0.0423

Appendix Table 43: Correlations between Right Ankle Torques and Performing Factors

1.2 Knee

1.2.1 Right Knee Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	0.267	0.262	0.545
	p-value	0.0486	0.0533	<0.001
EARLY BS	correlation	0.075	0.034	0.249
	p-value	0.586	0.804	0.0814
LATE BS	correlation	0.037	0.085	0.200
	p-value	0.79	0.535	0.164
INITIAL DS	correlation	-0.110	0.163	-0.004
	p-value	0.423	0.236	0.981
IMPACT	correlation	0.225	0.309	-0.264
	p-value	0.0985	0.0215	0.0642
EARLY FT	correlation	0.039	-0.036	-0.241
	p-value	0.779	0.791	0.0914
FINISH	correlation	0.319	0.195	0.283
	p-value	0.0177	0.154	0.0464
EXTERNAL-INTERNAL ROTATION				
ADDRESS	correlation	-0.028	0.193	0.307
	p-value	0.839	0.158	0.03
EARLY BS	correlation	0.119	0.293	0.246
	p-value	0.388	0.0299	0.0855
LATE BS	correlation	0.230	0.279	0.303
	p-value	0.0912	0.0389	0.0326
INITIAL DS	correlation	0.245	0.259	0.561
	p-value	0.0711	0.0565	<0.001
IMPACT	correlation	-0.073	0.109	0.317
	p-value	0.599	0.428	0.0248
EARLY FT	correlation	0.283	0.333	0.351
	p-value	0.0363	0.0131	0.0125
FINISH	correlation	-0.018	0.107	-0.015
	p-value	0.899	0.436	0.919

Appendix Table 44: Correlations between Right Knee Angle and Performing Factors

1.2.2 Left Knee

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.231	-0.171	0.484
	p-value	0.0897	0.213	<0.001
EARLY BS	correlation	-0.196	-0.281	0.033
	p-value	0.152	0.0374	0.819
LATE BS	correlation	-0.233	-0.214	-0.011
	p-value	0.0865	0.116	0.939
INITIAL DS	correlation	-0.107	0.013	-0.034
	p-value	0.439	0.926	0.813
IMPACT	correlation	0.086	0.457	-0.007
	p-value	0.533	0.001	0.963
EARLY FT	correlation	0.012	0.357	0.065
	p-value	0.934	0.0075	0.652
FINISH	correlation	-0.137	-0.203	0.405
	p-value	0.319	0.137	0.00357
EXTERNAL-INTERNAL ROTATION				
ADDRESS	correlation	-0.221	-0.026	0.004
	p-value	0.106	0.849	0.98
EARLY BS	correlation	-0.368	-0.075	0.009
	p-value	0.00566	0.584	0.949
LATE BS	correlation	-0.375	-0.058	-0.131
	p-value	0.0048	0.676	0.365
INITIAL DS	correlation	-0.179	0.141	0.031
	p-value	0.19	0.305	0.829
IMPACT	correlation	0.262	0.064	0.222
	p-value	0.053	0.642	0.121
EARLY FT	correlation	0.361	0.284	0.330
	p-value	0.00681	0.0359	0.0193
FINISH	correlation	0.386	0.413	-0.103
	p-value	0.00364	0.00174	0.475

Appendix Table 45: Correlations between Left Knee Angle and Performing Factors

1.2.3 Knee Angular Velocity

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
RIGHT				
ADDRESS	correlation	0.338	0.190	0.272
	p-value	0.0117	0.165	0.056
EARLY BS	correlation	0.134	0.359	0.005
	p-value	0.329	0.00715	0.971
LATE BS	correlation	-0.073	0.173	-0.111
	p-value	0.594	0.208	0.443
INITIAL DS	correlation	-0.273	0.221	-0.101
	p-value	0.0441	0.104	0.487
IMPACT	correlation	0.520	0.660	0.192
	p-value	0.001	0.001	0.187
EARLY FT	correlation	-0.232	-0.017	0.177
	p-value	0.0919	0.905	0.223
FINISH	correlation	0.282	0.351	0.076
	p-value	0.0367	0.00858	0.602
LEFT				
ADDRESS	correlation	-0.179	0.027	0.295
	p-value	0.192	0.847	0.0379
EARLY BS	correlation	0.275	0.274	-0.274
	p-value	0.0422	0.0431	0.0542
LATE BS	correlation	0.352	0.619	-0.016
	p-value	0.00834	0.001	0.912
INITIAL DS	correlation	0.024	0.070	0.047
	p-value	0.862	0.612	0.746
IMPACT	correlation	0.268	0.211	0.010
	p-value	0.05	0.126	0.943
EARLY FT	correlation	0.121	0.181	0.080
	p-value	0.383	0.191	0.586
FINISH	correlation	0.461	0.225	-0.048
	p-value	0.001	0.0979	0.742

Appendix Table 46: Correlations between Knee Angular Velocity and Performing Factors

1.2.4 Right Knee Torque

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
X_component				
ADDRESS	correlation	0.342	0.368	0.589
	p-value	0.0152	0.00859	<0.001

EARLY BS	correlation	0.344	0.455	0.259
	p-value	0.0146	<0.001	0.0688
LATE BS	correlation	0.058	0.325	0.145
	p-value	0.687	0.0211	0.317
INITIAL DS	correlation	0.197	-0.160	-0.295
	p-value	0.17	0.268	0.0378
IMPACT	correlation	0.340	0.240	-0.073
	p-value	0.0156	0.0926	0.616
EARLY FT	correlation	-0.350	-0.081	-0.380
	p-value	0.0128	0.574	0.00654
FINISH	correlation	0.445	0.389	0.284
	p-value	0.00122	0.00524	0.0457
Y_component				
ADDRESS	correlation	0.050	0.088	0.422
	p-value	0.731	0.542	0.00224
EARLY BS	correlation	-0.322	-0.200	0.014
	p-value	0.0228	0.164	0.92
LATE BS	correlation	-0.481	-0.301	-0.080
	p-value	<0.001	0.0337	0.58
INITIAL DS	correlation	-0.204	-0.113	-0.322
	p-value	0.156	0.433	0.0226
IMPACT	correlation	0.317	0.119	-0.030
	p-value	0.025	0.408	0.838
EARLY FT	correlation	0.373	-0.011	-0.108
	p-value	0.00762	0.937	0.457
FINISH	correlation	-0.159	-0.168	-0.315
	p-value	0.271	0.243	0.0258
Z_component				
ADDRESS	correlation	-0.275	-0.077	0.278
	p-value	0.0535	0.595	0.0504
EARLY BS	correlation	-0.408	-0.148	0.112
	p-value	0.00323	0.305	0.441
LATE BS	correlation	-0.312	-0.212	-0.061
	p-value	0.0272	0.14	0.674
INITIAL DS	correlation	0.032	0.087	0.052
	p-value	0.826	0.547	0.719
IMPACT	correlation	0.622	0.251	0.328
	p-value	<0.001	0.0788	0.0202
EARLY FT	correlation	0.500	0.163	0.119
	p-value	<0.001	0.259	0.41
FINISH	correlation	-0.037	-0.026	-0.279
	p-value	0.8	0.858	0.0498

Appendix Table 47: Correlations between Right Knee Torque and Performing Factors

1.2.5 Left Knee Torque

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
X_component				
ADDRESS	correlation	-0.149	0.057	-0.224
	p-value	0.301	0.692	0.117
EARLY BS	correlation	-0.339	-0.217	-0.325
	p-value	0.0161	0.13	0.0212
LATE BS	correlation	0.047	0.233	-0.450
	p-value	0.748	0.104	0.00104
INITIAL DS	correlation	0.241	0.461	-0.151
	p-value	0.0917	<0.001	0.295
IMPACT	correlation	0.672	0.521	0.330
	p-value	<0.001	<0.001	0.0193
EARLY FT	correlation	0.138	0.111	0.340
	p-value	0.339	0.443	0.0157
FINISH	correlation	0.363	0.314	0.071
	p-value	0.00962	0.0264	0.622
Y_component				
ADDRESS	correlation	0.013	0.047	0.136
	p-value	0.926	0.745	0.345
EARLY BS	correlation	-0.152	-0.251	0.199
	p-value	0.293	0.0784	0.166
LATE BS	correlation	-0.203	0.039	-0.242
	p-value	0.157	0.787	0.0901
INITIAL DS	correlation	-0.373	0.191	0.219
	p-value	0.00755	0.183	0.126
IMPACT	correlation	-0.475	-0.468	0.267
	p-value	<0.001	<0.001	0.0607
EARLY FT	correlation	-0.014	-0.222	-0.079
	p-value	0.921	0.121	0.584
FINISH	correlation	-0.183	-0.256	-0.424
	p-value	0.204	0.0732	0.00215
Z_component				
ADDRESS	correlation	0.166	0.135	-0.092
	p-value	0.249	0.351	0.526
EARLY BS	correlation	0.274	0.305	0.133
	p-value	0.0546	0.0311	0.357
LATE BS	correlation	-0.005	0.171	-0.360
	p-value	0.97	0.236	0.0103
INITIAL DS	correlation	-0.392	0.025	0.160
	p-value	0.00481	0.864	0.266
IMPACT	correlation	-0.775	-0.519	-0.022

	p-value	<0.001	<0.001	0.881
EARLY FT	correlation	-0.228	-0.175	0.115
	p-value	0.111	0.225	0.426
FINISH	correlation	-0.338	-0.288	0.012
	p-value	0.0163	0.0426	0.932

Appendix Table 48: Correlations between Left Knee Torque and Performing Factors

1.3 Hip

1.3.1 Right Hip Angle

Right Hip Angle		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.521	-0.286	-0.245
	p-value	0.001	0.0342	0.0868
EARLY BS	correlation	-0.469	-0.237	-0.201
	p-value	0.001	0.0812	0.161
LATE BS	correlation	-0.436	-0.303	-0.111
	p-value	0.001	0.0246	0.443
INITIAL DS	correlation	-0.464	-0.515	0.021
	p-value	0.001	0.001	0.888
IMPACT	correlation	-0.453	-0.473	0.140
	p-value	0.001	0.001	0.333
EARLY FT	correlation	-0.516	-0.441	-0.028
	p-value	0.001	0.001	0.848
FINISH	correlation	-0.746	-0.679	0.048
	p-value	0.001	0.001	0.743
ABDUCTION -ADDUCTION				
ADDRESS	correlation	0.339	-0.021	0.358
	p-value	0.0115	0.881	0.0107
EARLY BS	correlation	0.124	0.114	0.179
	p-value	0.365	0.408	0.213
LATE BS	correlation	0.097	0.123	0.090
	p-value	0.481	0.37	0.533
INITIAL DS	correlation	0.140	0.139	-0.061
	p-value	0.307	0.313	0.675
IMPACT	correlation	0.181	0.062	-0.073
	p-value	0.185	0.654	0.614
EARLY FT	correlation	0.208	-0.036	-0.218
	p-value	0.128	0.795	0.128
FINISH	correlation	-0.141	-0.059	-0.042
	p-value	0.305	0.668	0.773
EXTERNAL – INTERNAL ROTATION				

ADDRESS	correlation	-0.482	-0.458	-0.010
	p-value	0.001	0.001	0.944
EARLY BS	correlation	-0.288	-0.340	0.102
	p-value	0.0333	0.0112	0.48
LATE BS	correlation	-0.074	-0.198	0.242
	p-value	0.59	0.147	0.0904
INITIAL DS	correlation	-0.310	-0.305	0.040
	p-value	0.0213	0.0233	0.783
IMPACT	correlation	-0.349	-0.505	-0.204
	p-value	0.00895	0.001	0.156
EARLY FT	correlation	-0.355	-0.308	-0.270
	p-value	0.00777	0.0223	0.0581
FINISH	correlation	-0.336	-0.350	-0.426
	p-value	0.0122	0.00878	0.00205

Appendix Table 49: Correlations between Right Hip Angle and Performing Factors

1.3.2 Left Hip Angle

Left Hipe Angle		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.255	-0.031	-0.124
	p-value	0.0603	0.823	0.392
EARLY BS	correlation	-0.361	-0.050	-0.125
	p-value	0.00677	0.719	0.389
LATE BS	correlation	-0.377	-0.112	-0.088
	p-value	0.00455	0.414	0.541
INITIAL DS	correlation	-0.406	-0.289	0.039
	p-value	0.00211	0.0323	0.785
IMPACT	correlation	-0.286	-0.526	-0.122
	p-value	0.0346	0.001	0.4
EARLY FT	correlation	-0.194	-0.411	-0.251
	p-value	0.156	0.00184	0.0781
FINISH	correlation	-0.359	-0.395	-0.226
	p-value	0.00704	0.00287	0.115
ABDUCTION -ADDUCTION				
ADDRESS	correlation	-0.171	0.302	0.145
	p-value	0.211	0.0249	0.314
EARLY BS	correlation	-0.115	-0.107	0.029
	p-value	0.402	0.437	0.841
LATE BS	correlation	-0.051	-0.120	0.113
	p-value	0.713	0.383	0.434
INITIAL DS	correlation	-0.114	-0.147	0.167
	p-value	0.407	0.283	0.248

IMPACT	correlation	-0.007	0.001	-0.034
	p-value	0.957	0.993	0.813
EARLY FT	correlation	-0.053	-0.104	0.081
	p-value	0.702	0.448	0.578
FINISH	correlation	0.794	0.463	-0.106
	p-value	0.001	0.001	0.463
EXTERNAL – INTERNAL ROTATION				
ADDRESS	correlation	-0.214	-0.419	-0.198
	p-value	0.116	0.00146	0.168
EARLY BS	correlation	-0.110	-0.298	-0.176
	p-value	0.424	0.0271	0.221
LATE BS	correlation	-0.114	-0.317	-0.154
	p-value	0.409	0.0183	0.286
INITIAL DS	correlation	-0.009	-0.413	-0.282
	p-value	0.946	0.00174	0.0472
IMPACT	correlation	-0.155	-0.438	-0.125
	p-value	0.26	0.001	0.386
EARLY FT	correlation	0.200	-0.266	-0.314
	p-value	0.143	0.0493	0.0266
FINISH	correlation	-0.050	-0.147	-0.010
	p-value	0.719	0.283	0.944

Appendix Table 50: Correlations between Left Hip Angle and Performing Factors

1.3.3 Hip Angular Velocity

Hip Angular Velocity		Club Head Speed at impact	Horizontal Launch Angle	Handicap
RIGHT				
ADDRESS	correlation	0.227	0.316	0.194
	p-value	0.0959	0.0188	0.176
EARLY BS	correlation	0.200	0.027	0.080
	p-value	0.147	0.847	0.584
LATE BS	correlation	0.065	0.205	0.053
	p-value	0.639	0.133	0.715
INITIAL DS	correlation	-0.354	0.045	0.137
	p-value	0.0081	0.747	0.343
IMPACT	correlation	0.404	0.523	0.075
	p-value	0.00245	0.001	0.61
EARLY FT	correlation	0.099	0.076	0.132
	p-value	0.478	0.587	0.367
FINISH	correlation	0.132	0.050	0.036
	p-value	0.336	0.718	0.802
LEFT				
ADDRESS	correlation	0.099	0.266	0.274

	p-value	0.473	0.05	0.0543
EARLY BS	correlation	0.541	0.148	0.324
	p-value	0.001	0.281	0.0215
LATE BS	correlation	0.320	0.304	0.228
	p-value	0.0172	0.0242	0.112
INITIAL DS	correlation	-0.328	0.148	0.196
	p-value	0.0144	0.282	0.172
IMPACT	correlation	0.306	0.237	-0.038
	p-value	0.0229	0.082	0.795
EARLY FT	correlation	0.415	0.422	0.227
	p-value	0.00165	0.00134	0.114
FINISH	correlation	0.285	0.190	0.043
	p-value	0.035	0.165	0.769

Appendix Table 51: Correlations between Hip Angular Velocity and Performing Factors

1.3.4 Right Hip Torque

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
X_component				
ADDRESS	correlation	-0.463	-0.352	-0.530
	p-value	<0.001	0.0121	<0.001
EARLY BS	correlation	-0.531	-0.266	-0.142
	p-value	<0.001	0.0623	0.325
LATE BS	correlation	-0.413	-0.286	-0.119
	p-value	0.00285	0.0443	0.412
INITIAL DS	correlation	0.088	0.176	0.450
	p-value	0.544	0.222	0.00103
IMPACT	correlation	-0.036	-0.084	0.213
	p-value	0.802	0.561	0.137
EARLY FT	correlation	-0.064	-0.170	0.225
	p-value	0.66	0.237	0.117
FINISH	correlation	-0.228	-0.248	-0.292
	p-value	0.111	0.083	0.0398
Y_component				
ADDRESS	correlation	-0.376	-0.236	0.199
	p-value	0.00704	0.0993	0.166
EARLY BS	correlation	0.088	-0.142	0.078
	p-value	0.544	0.324	0.592
LATE BS	correlation	-0.025	-0.143	0.050
	p-value	0.863	0.322	0.731
INITIAL DS	correlation	-0.298	-0.348	-0.243
	p-value	0.0357	0.0131	0.089

IMPACT	correlation	-0.278	-0.207	0.386
	p-value	0.0506	0.15	0.00564
EARLY FT	correlation	-0.008	0.217	0.528
	p-value	0.957	0.13	<0.001
FINISH	correlation	-0.066	0.030	0.134
	p-value	0.649	0.838	0.355
Z_component				
ADDRESS	correlation	-0.620	-0.494	0.402
	p-value	<0.001	<0.001	0.00378
EARLY BS	correlation	-0.360	0.017	0.129
	p-value	0.0102	0.909	0.371
LATE BS	correlation	-0.411	-0.064	-0.078
	p-value	0.00301	0.661	0.591
INITIAL DS	correlation	-0.207	-0.016	-0.237
	p-value	0.15	0.912	0.0973
IMPACT	correlation	-0.084	-0.440	0.249
	p-value	0.56	0.00137	0.0818
EARLY FT	correlation	0.435	0.430	0.383
	p-value	0.00159	0.00182	0.00611
FINISH	correlation	0.214	0.197	0.030
	p-value	0.136	0.171	0.837

Appendix Table 52: Correlations between Right Hip Torque and Performing Factors

1.3.5 Left Hip Torque

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
X_component				
ADDRESS	correlation	0.302	0.260	0.277
	p-value	0.0332	0.0678	0.0517
EARLY BS	correlation	0.445	0.255	0.347
	p-value	0.0012	0.0736	0.0136
LATE BS	correlation	0.167	-0.042	0.478
	p-value	0.247	0.771	<0.001
INITIAL DS	correlation	-0.334	-0.304	0.334
	p-value	0.0176	0.0321	0.0177
IMPACT	correlation	-0.117	-0.123	-0.210
	p-value	0.417	0.393	0.142
EARLY FT	correlation	0.143	0.114	-0.402
	p-value	0.323	0.43	0.00377
FINISH	correlation	-0.287	-0.330	-0.085
	p-value	0.043	0.0194	0.557
Y_component				

ADDRESS	correlation	0.203	0.068	0.362
	p-value	0.158	0.636	0.00968
EARLY BS	correlation	0.353	0.083	0.584
	p-value	0.012	0.568	<0.001
LATE BS	correlation	0.582	0.180	0.660
	p-value	<0.001	0.212	<0.001
INITIAL DS	correlation	0.794	0.491	0.290
	p-value	<0.001	<0.001	0.041
IMPACT	correlation	0.597	0.606	0.162
	p-value	<0.001	<0.001	0.262
EARLY FT	correlation	-0.252	-0.171	0.204
	p-value	0.0769	0.235	0.156
FINISH	correlation	0.059	0.145	-0.030
	p-value	0.686	0.316	0.834
Z_component				
ADDRESS	correlation	-0.072	-0.148	0.036
	p-value	0.62	0.304	0.806
EARLY BS	correlation	0.099	-0.172	0.291
	p-value	0.493	0.232	0.0405
LATE BS	correlation	-0.193	-0.383	0.285
	p-value	0.18	0.00611	0.0447
INITIAL DS	correlation	-0.542	-0.319	0.004
	p-value	<0.001	0.0239	0.977
IMPACT	correlation	-0.623	-0.639	0.097
	p-value	<0.001	<0.001	0.503
EARLY FT	correlation	0.178	0.156	-0.136
	p-value	0.217	0.278	0.346
FINISH	correlation	-0.196	-0.202	0.137
	p-value	0.172	0.159	0.344

Appendix Table 53: Correlations between Left Hip Torque and Performing Factors

1.4 Pelvis

1.4.1 Pelvis Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.409	-0.214	0.265
	p-value	0.00196	0.117	0.0625
EARLY BS	correlation	-0.593	-0.338	0.016
	p-value	0.001	0.0116	0.915
LATE BS	correlation	-0.579	-0.365	0.061
	p-value	0.001	0.0061	0.675

INITIAL DS	correlation	-0.571	-0.526	0.094
	p-value	0.001	0.001	0.518
IMPACT	correlation	-0.212	-0.242	-0.025
	p-value	0.12	0.0746	0.861
EARLY FT	correlation	-0.248	-0.265	-0.176
	p-value	0.0675	0.0505	0.223
FINISH	correlation	0.154	-0.084	-0.102
	p-value	0.261	0.544	0.482
LATERAL FLEXION				
ADDRESS	correlation	0.631	0.270	0.414
	p-value	0.001	0.0464	0.00279
EARLY BS	correlation	-0.413	-0.463	-0.313
	p-value	0.00174	0.001	0.0269
LATE BS	correlation	-0.474	-0.467	-0.445
	p-value	0.001	0.001	0.00119
INITIAL DS	correlation	-0.281	-0.361	-0.535
	p-value	0.0377	0.00669	<0.001
IMPACT	correlation	0.480	0.284	0.486
	p-value	0.001	0.0359	<0.001
EARLY FT	correlation	0.585	0.421	0.411
	p-value	0.001	0.00135	0.00303
FINISH	correlation	0.241	0.280	0.549
	p-value	0.0758	0.0382	<0.001
RIGHT - LEFT ROTATION				
ADDRESS	correlation	-0.327	-0.399	-0.525
	p-value	0.0147	0.00252	<0.001
EARLY BS	correlation	-0.332	-0.356	-0.367
	p-value	0.0134	0.00765	0.00867
LATE BS	correlation	-0.484	-0.375	-0.419
	p-value	0.001	0.00477	0.00247
INITIAL DS	correlation	-0.253	-0.319	-0.263
	p-value	0.0624	0.0174	0.0654
IMPACT	correlation	0.178	0.057	0.105
	p-value	0.192	0.678	0.467
EARLY FT	correlation	0.467	0.237	0.298
	p-value	0.836	0.166	0.0356
FINISH	correlation	-0.067	-0.262	-0.249
	p-value	0.627	0.0538	0.0814

Appendix Table 54: Correlations between Pelvis Angle and Performing Factors

1.4.2 Pelvis Angular Velocity

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
ADDRESS	correlation	0.004	-0.243	0.020
	p-value	0.974	0.0733	0.892
EARLY BS	correlation	-0.087	-0.210	0.319
	p-value	0.529	0.123	0.024
LATE BS	correlation	-0.240	-0.345	0.013
	p-value	0.0777	0.00979	0.93
INITIAL DS	correlation	-0.421	0.068	-0.067
	p-value	0.00135	0.621	0.644
IMPACT	correlation	-0.284	-0.367	-0.268
	p-value	0.0357	0.00581	0.0596
EARLY FT	correlation	-0.183	-0.193	-0.102
	p-value	0.182	0.158	0.481
FINISH	correlation	0.080	0.000	-0.128
	p-value	0.56	1	0.375

Appendix Table 55: Correlations between Pelvis Angular Velocity and Performing Factors

1.5 Trunk

1.5.1 Trunk Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	0.504	0.060	0.214
	p-value	0.001	0.664	0.137
EARLY BS	correlation	0.471	0.012	0.158
	p-value	0.001	0.928	0.272
LATE BS	correlation	0.424	-0.061	0.208
	p-value	0.00127	0.661	0.147
INITIAL DS	correlation	0.326	-0.123	0.079
	p-value	0.015	0.37	0.584
IMPACT	correlation	0.520	0.082	-0.182
	p-value	0.001	0.551	0.205
EARLY FT	correlation	0.095	-0.317	-0.112
	p-value	0.49	0.0183	0.44
FINISH	correlation	-0.451	-0.571	-0.115
	p-value	0.001	0.001	0.427
LATERAL INCLINATION				
ADDRESS	correlation	0.530	0.178	0.302
	p-value	0.001	0.192	0.0328

EARLY BS	correlation	-0.371	-0.105	0.112
	p-value	0.00524	0.446	0.44
LATE BS	correlation	-0.447	-0.137	-0.063
	p-value	0.001	0.318	0.661
INITIAL DS	correlation	-0.460	-0.021	-0.170
	p-value	0.001	0.879	0.238
IMPACT	correlation	0.735	0.359	0.138
	p-value	0.001	0.00719	0.34
EARLY FT	correlation	0.741	0.492	0.221
	p-value	0.001	0.001	0.123
FINISH	correlation	0.461	0.192	0.274
	p-value	0.001	0.161	0.0545
RIGHT - LEFT ROTATION				
ADDRESS	correlation	0.197	0.146	-0.054
	p-value	0.15	0.289	0.709
EARLY BS	correlation	-0.237	-0.273	0.196
	p-value	0.0814	0.0437	0.172
LATE BS	correlation	0.016	-0.328	0.163
	p-value	0.908	0.0145	0.259
INITIAL DS	correlation	0.106	-0.226	0.005
	p-value	0.443	0.0973	0.971
IMPACT	correlation	0.139	-0.014	0.115
	p-value	0.313	0.918	0.426
EARLY FT	correlation	0.374	0.349	-0.239
	p-value	0.00495	0.00891	0.0942
FINISH	correlation	0.404	0.518	0.209
	p-value	0.00225	0.001	0.145

Appendix Table 56: Correlations between Trunk Angle and Performing Factors

1.5.2 Trunk Angular Velocity

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
ADDRESS	correlation	-0.311	-0.303	-0.194
	p-value	0.0206	0.0246	0.178
EARLY BS	correlation	-0.459	-0.604	-0.008
	p-value	0.001	0.001	0.956
LATE BS	correlation	-0.492	-0.574	-0.359
	p-value	0.001	0.001	0.0104
INITIAL DS	correlation	0.563	0.120	0.266
	p-value	0.001	0.383	0.0619
IMPACT	correlation	0.394	0.482	0.089
	p-value	0.0029	0.001	0.541
EARLY FT	correlation	0.239	0.308	-0.294
	p-value	0.0789	0.022	0.0384
FINISH	correlation	-0.093	0.077	-0.089
	p-value	0.497	0.578	0.537

Appendix Table 57: Correlations between Trunk Angular Velocity and Performing Factors

1.6 Head

1.6.1 Head Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.114	-0.080	0.049
	p-value	0.406	0.561	0.735
EARLY BS	correlation	0.108	-0.010	0.015
	p-value	0.435	0.943	0.919
LATE BS	correlation	0.094	-0.001	-0.028
	p-value	0.496	0.992	0.846
INITIAL DS	correlation	0.172	0.095	-0.095
	p-value	0.210	0.491	0.512
IMPACT	correlation	-0.052	0.059	0.159
	p-value	0.706	0.668	0.27
EARLY FT	correlation	-0.356	-0.210	0.238
	p-value	0.008	0.124	0.0967
FINISH	correlation	-0.701	-0.629	0.388
	p-value	0.001	0.001	0.00542
LATERAL INCLINATION				
ADDRESS	correlation	0.691	0.463	0.142

	p-value	0.001	0.001	0.325
EARLY BS	correlation	0.428	0.142	-0.144
	p-value	0.001	0.301	0.317
LATE BS	correlation	0.183	0.006	-0.302
	p-value	0.180	0.965	0.0333
INITIAL DS	correlation	0.248	-0.018	-0.469
	p-value	0.068	0.898	<0.001
IMPACT	correlation	0.441	0.392	0.204
	p-value	0.001	0.003	0.156
EARLY FT	correlation	0.374	0.340	0.367
	p-value	0.005	0.011	0.00868
FINISH	correlation	-0.208	0.119	0.328
	p-value	0.691	0.463	0.0202
RIGHT - LEFT ROTATION				
ADDRESS	correlation	-0.201	-0.390	-0.544
	p-value	0.142	0.003	<0.001
EARLY BS	correlation	-0.001	-0.202	-0.409
	p-value	0.994	0.139	0.00319
LATE BS	correlation	-0.165	-0.068	-0.485
	p-value	0.228	0.619	<0.001
INITIAL DS	correlation	0.014	0.161	-0.472
	p-value	0.917	0.240	<0.001
IMPACT	correlation	0.411	0.496	-0.089
	p-value	0.002	0.001	0.541
EARLY FT	correlation	0.509	0.610	0.104
	p-value	0.001	0.001	0.471
FINISH	correlation	-0.422	-0.019	-0.028
	p-value	0.001	0.888	0.845

Appendix Table 58: Correlations between Head Angle and Performing Factors

1.6.2 Head Angular Velocity

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
ADDRESS	correlation	0.369	0.537	0.132
	p-value	0.006	0.001	0.361
EARLY BS	correlation	0.499	0.638	-0.004
	p-value	0.001	0.001	0.981
LATE BS	correlation	0.401	0.622	0.229
	p-value	0.002	0.001	0.109
INITIAL DS	correlation	-0.355	0.127	0.009
	p-value	0.008	0.355	0.948
IMPACT	correlation	0.282	0.240	-0.132

	p-value	0.037	0.078	0.36
EARLY FT	correlation	0.186	-0.072	-0.135
	p-value	0.173	0.601	0.35
FINISH	correlation	-0.114	-0.122	-0.131
	p-value	0.409	0.375	0.366

Appendix Table 59: Correlations between Head Angular Velocity and Performing Factors

1.7 Shoulder

1.7.1 Right Shoulder Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.027	0.365	0.101
	p-value	0.843	0.006	0.487
EARLY BS	correlation	0.095	0.212	-0.238
	p-value	0.492	0.120	0.0964
LATE BS	correlation	-0.306	-0.493	-0.174
	p-value	0.023	0.001	0.228
INITIAL DS	correlation	0.284	0.060	0.228
	p-value	0.036	0.662	0.112
IMPACT	correlation	0.119	0.383	0.058
	p-value	0.388	0.004	0.69
EARLY FT	correlation	0.304	0.615	-0.279
	p-value	0.024	0.001	0.0501
FINISH	correlation	-0.018	0.006	0.453
	p-value	0.894	0.967	<0.001
PRONATION - SUPINATION				
ADDRESS	correlation	-0.032	-0.301	-0.018
	p-value	0.815	0.026	0.902
EARLY BS	correlation	0.061	-0.157	-0.384
	p-value	0.660	0.252	0.00585
LATE BS	correlation	0.337	0.096	-0.578
	p-value	0.012	0.487	<0.001
INITIAL DS	correlation	0.175	0.096	-0.500
	p-value	0.201	0.485	<0.001
IMPACT	correlation	0.075	-0.149	-0.375
	p-value	0.585	0.277	0.00737
EARLY FT	correlation	-0.102	-0.349	-0.296
	p-value	0.459	0.009	0.0369
FINISH	correlation	0.143	-0.494	-0.052
	p-value	0.299	0.001	0.72

Appendix Table 60: Correlations between Right Shoulder Angle and Performing Factors

1.7.2 Left Shoulder

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	0.025	0.401	-0.152
	p-value	0.858	0.002	0.292
EARLY BS	correlation	-0.008	0.538	0.023
	p-value	0.956	0.001	0.872
LATE BS	correlation	-0.128	0.277	0.180
	p-value	0.354	0.041	0.211
INITIAL DS	correlation	0.348	0.273	0.386
	p-value	0.009	0.044	0.00558
IMPACT	correlation	-0.064	- 0.112	0.418
	p-value	0.641	0.416	0.00254
EARLY FT	correlation	0.424	0.248	0.083
	p-value	0.001	0.068	0.567
FINISH	correlation	-0.322	- 0.375	0.164
	p-value	0.017	0.005	0.256
EXTERNAL – INTERNAL ROTATION				
ADDRESS	correlation	-0.324	0.081	0.117
	p-value	0.016	0.555	0.42
EARLY BS	correlation	-0.107	- 0.017	-0.149
	p-value	0.435	0.900	0.3
LATE BS	correlation	0.065	0.023	-0.283
	p-value	0.638	0.866	0.0468
INITIAL DS	correlation	0.094	0.403	-0.203
	p-value	0.495	0.002	0.157
IMPACT	correlation	-0.059	- 0.005	-0.195
	p-value	0.669	0.973	0.174
EARLY FT	correlation	-0.161	0.291	0.062
	p-value	0.242	0.031	0.668
FINISH	correlation	0.392	0.235	0.316
	p-value	0.003	0.084	0.0251

Appendix Table 61: Correlations between Left Shoulder Angle and Performing Factors

1.7.3 Shoulder Angular Velocity

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
RIGHT				
ADDRESS	correlation	0.068	- 0.418	0.072
	p-value	0.622	0.002	0.621
EARLY BS	correlation	0.369	0.599	-0.360
	p-value	0.006	0.001	0.0103
LATE BS	correlation	0.321	0.610	0.059
	p-value	0.017	0.001	0.686
INITIAL DS	correlation	-0.055	- 0.290	-0.340
	p-value	0.688	0.032	0.0158
IMPACT	correlation	-0.489	- 0.015	0.310
	p-value	0.001	0.916	0.0287
EARLY FT	correlation	-0.119	0.423	0.255
	p-value	0.385	0.001	0.0743
FINISH	correlation	0.015	0.299	-0.264
	p-value	0.912	0.027	0.0642
LEFT				
ADDRESS	correlation	0.299	- 0.066	0.025
	p-value	0.027	0.631	0.861
EARLY BS	correlation	0.440	- 0.152	-0.254
	p-value	0.001	0.268	0.075
LATE BS	correlation	0.303	- 0.275	-0.241
	p-value	0.025	0.043	0.0923
INITIAL DS	correlation	-0.043	0.332	0.529
	p-value	0.754	0.013	<0.001
IMPACT	correlation	-0.116	0.321	0.026
	p-value	0.398	0.017	0.859
EARLY FT	correlation	-0.147	0.103	0.213
	p-value	0.285	0.453	0.137
FINISH	correlation	-0.039	- 0.137	-0.219
	p-value	0.776	0.318	0.126

Appendix Table 62: Correlations between Shoulder Angular Velocity and Performing Factors

1.8 Elbow

1.8.1 Right Elbow Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.237	- 0.494	-0.101
	p-value	0.082	0.001	0.485
EARLY BS	correlation	-0.050	- 0.018	0.285
	p-value	0.717	0.895	0.0452
LATE BS	correlation	0.030	0.333	0.361
	p-value	0.827	0.013	0.01
INITIAL DS	correlation	0.100	0.541	0.318
	p-value	0.468	0.001	0.0246
IMPACT	correlation	-0.151	- 0.109	0.476
	p-value	0.272	0.426	<0.001
EARLY FT	correlation	0.089	0.182	0.248
	p-value	0.518	0.184	0.0822
FINISH	correlation	0.200	0.589	0.306
	p-value	0.144	0.001	0.0305
EXTERNAL – INTERNAL ROTATION				
ADDRESS	correlation	-0.209	- 0.256	0.230
	p-value	0.126	0.060	0.109
EARLY BS	correlation	-0.353	- 0.105	0.260
	p-value	0.008	0.447	0.0678
LATE BS	correlation	-0.446	- 0.201	0.247
	p-value	0.001	0.141	0.0838
INITIAL DS	correlation	-0.340	- 0.535	0.309
	p-value	0.011	0.001	0.0289
IMPACT	correlation	-0.340	- 0.575	-0.115
	p-value	0.011	0.001	0.428
EARLY FT	correlation	-0.377	- 0.541	0.024
	p-value	0.005	0.001	0.869
FINISH	correlation	-0.344	- 0.280	0.399
	p-value	0.010	0.038	0.00414

Appendix Table 63: Correlations between Right Elbow Angle and Performing Factors

1.8.2 Left Elbow Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.168	0.086	-0.507
	p-value	0.221	0.531	<0.001
EARLY BS	correlation	0.180	0.521	-0.483
	p-value	0.188	0.001	<0.001
LATE BS	correlation	0.188	0.557	-0.054
	p-value	0.168	0.001	0.711
INITIAL DS	correlation	0.208	0.564	0.217
	p-value	0.128	0.001	0.13
IMPACT	correlation	0.162	0.324	0.473
	p-value	0.238	0.016	<0.001
EARLY FT	correlation	-0.220	- 0.634	0.262
	p-value	0.107	0.001	0.0658
FINISH	correlation	0.259	0.627	0.292
	p-value	0.056	0.001	0.0399
EXTERNAL – INTERNAL ROTATION				
ADDRESS	correlation	-0.672	- 0.562	-0.190
	p-value	0.001	0.001	0.187
EARLY BS	correlation	-0.541	- 0.629	-0.431
	p-value	0.001	0.001	0.00176
LATE BS	correlation	-0.454	- 0.397	-0.383
	p-value	0.001	0.003	0.00608
INITIAL DS	correlation	0.017	- 0.015	-0.034
	p-value	0.902	0.913	0.816
IMPACT	correlation	-0.411	- 0.422	0.158
	p-value	0.002	0.001	0.272
EARLY FT	correlation	-0.608	- 0.609	-0.031
	p-value	0.001	0.001	0.829
FINISH	correlation	-0.168	- 0.094	0.184
	p-value	0.220	0.495	0.201

Appendix Table 64: Correlations between Left Elbow Angle and Performing Factors

1.8.3 Elbow Angular Velocity

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
RIGHT				
ADDRESS	correlation	0.378	0.306	0.348
	p-value	0.004	0.023	0.0134
EARLY BS	correlation	0.090	0.523	0.227
	p-value	0.516	0.001	0.113
LATE BS	correlation	0.370	0.609	0.408
	p-value	0.005	0.001	0.00323
INITIAL DS	correlation	0.662	0.517	0.082
	p-value	0.001	0.001	0.569
IMPACT	correlation	0.039	0.262	0.043
	p-value	0.777	0.053	0.766
EARLY FT	correlation	0.158	0.094	-0.101
	p-value	0.249	0.493	0.484
FINISH	correlation	-0.078	- 0.211	0.127
	p-value	0.571	0.122	0.379
LEFT				
ADDRESS	correlation	0.418	0.261	0.537
	p-value	0.002	0.054	<0.001
EARLY BS	correlation	0.163	0.257	-0.040
	p-value	0.234	0.058	0.782
LATE BS	correlation	0.158	0.075	0.209
	p-value	0.251	0.586	0.145
INITIAL DS	correlation	0.139	- 0.040	-0.503
	p-value	0.310	0.773	<0.001
IMPACT	correlation	-0.255	- 0.305	-0.438
	p-value	0.060	0.024	0.00147
EARLY FT	correlation	-0.030	0.366	-0.201
	p-value	0.830	0.006	0.162
FINISH	correlation	-0.089	- 0.017	-0.004
	p-value	0.524	0.905	0.979

Appendix Table 65: Correlations between Elbow Angular Velocity and Performing Factors

1.9 Hand

1.9.1 Right Hand Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	-0.539	- 0.386	-0.299
	p-value	0.001	0.004	0.0348
EARLY BS	correlation	-0.340	- 0.214	0.120
	p-value	0.011	0.116	0.405
LATE BS	correlation	-0.172	- 0.017	-0.209
	p-value	0.208	0.902	0.146
INITIAL DS	correlation	-0.229	- 0.310	-0.084
	p-value	0.092	0.021	0.564
IMPACT	correlation	-0.230	0.045	0.435
	p-value	0.095	0.748	0.0018
EARLY FT	correlation	-0.190	- 0.351	0.062
	p-value	0.164	0.009	0.667
FINISH	correlation	-0.502	- 0.394	-0.007
	p-value	0.001	0.004	0.965
ULNAR – RADIAL DEVIATION				
ADDRESS	correlation	-0.411	-0.767	-0.132
	p-value	0.002	0.001	0.361
EARLY BS	correlation	-0.415	- 0.444	0.389
	p-value	0.002	0.001	0.00524
LATE BS	correlation	-0.297	- 0.158	-0.165
	p-value	0.028	0.249	0.253
INITIAL DS	correlation	-0.487	-0.714	-0.302
	p-value	0.001	0.001	0.033
IMPACT	correlation	-0.275	-0.715	-0.508
	p-value	0.042	0.001	<0.001
EARLY FT	correlation	-0.385	- 0.453	0.178
	p-value	0.004	0.001	0.216
FINISH	correlation	-0.486	-0.633	-0.368
	p-value	0.001	0.001	0.0102

Appendix Table 66: Correlations between Right Hand Angle and Performing Factors

1.9.2 Left Hand Angle

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
FLEXION -EXTENSION				
ADDRESS	correlation	0.265	0.282	-0.277
	p-value	0.051	0.037	0.0511
EARLY BS	correlation	0.228	0.301	-0.583
	p-value	0.093	0.026	<0.001
LATE BS	correlation	0.248	0.128	-0.119
	p-value	0.068	0.352	0.41
INITIAL DS	correlation	0.257	0.176	-0.473
	p-value	0.058	0.197	<0.001
IMPACT	correlation	0.194	0.293	-0.717
	p-value	0.156	0.030	<0.001
EARLY FT	correlation	0.199	0.364	-0.482
	p-value	0.145	0.006	<0.001
FINISH	correlation	0.181	0.396	0.012
	p-value	0.196	0.003	0.937
ULNAR – RADIAL DEVIATION				
ADDRESS	correlation	-0.333	- 0.520	0.276
	p-value	0.013	0.001	0.0527
EARLY BS	correlation	0.060	- 0.232	-0.041
	p-value	0.665	0.088	0.777
LATE BS	correlation	0.146	- 0.049	0.078
	p-value	0.286	0.722	0.591
INITIAL DS	correlation	0.213	0.195	-0.301
	p-value	0.118	0.153	0.0334
IMPACT	correlation	0.208	0.038	-0.359
	p-value	0.128	0.783	0.0105
EARLY FT	correlation	-0.110	0.054	-0.351
	p-value	0.426	0.694	0.0125
FINISH	correlation	-0.099	- 0.262	-0.378
	p-value	0.481	0.058	0.00804

Appendix Table 67: Correlations between Left Hand Angle and Performing Factors

1.9.3 Hand Angular Velocity

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
RIGHT				
ADDRESS	correlation	0.482	0.463	0.269
	p-value	0.001	0.001	0.0593
EARLY BS	correlation	0.311	0.378	-0.344
	p-value	0.038	0.011	0.0299
LATE BS	correlation	0.163	0.313	0.335
	p-value	0.295	0.041	0.0395
INITIAL DS	correlation	0.199	- 0.125	-0.195
	p-value	0.145	0.364	0.175
IMPACT	correlation	0.065	- 0.044	-0.366
	p-value	0.635	0.751	0.00886
EARLY FT	correlation	0.438	0.603	0.419
	p-value	0.001	0.001	0.00247
FINISH	correlation	0.021	0.068	0.001
	p-value	0.883	0.628	0.995
LEFT				
ADDRESS	correlation	0.467	0.427	0.418
	p-value	0.001	0.001	0.00251
EARLY BS	correlation	0.284	0.429	0.069
	p-value	0.056	0.003	0.666
LATE BS	correlation	0.134	0.317	0.380
	p-value	0.381	0.034	0.0156
INITIAL DS	correlation	0.238	0.013	-0.446
	p-value	0.080	0.923	0.00117
IMPACT	correlation	0.201	0.363	-0.155
	p-value	0.142	0.006	0.281
EARLY FT	correlation	0.247	0.556	0.389
	p-value	0.069	0.001	0.00529
FINISH	correlation	-0.035	0.050	0.109
	p-value	0.808	0.723	0.465

Appendix Table 68: Correlations between Hand Angular Velocity and Performing Factors

1.10 X Factor

Position		Club Head Speed at Impact	Horizontal Launch Angle	Handicap
X_FACTOR_top	correlation	-0.138	0.242	0.174
	p-value*	0.341	0.0898	0.227
X_FACTOR_stretch_rel	correlation	0.045	-0.166	-0.755
	p-value*	0.755	0.25	<0.001
X_FACTOR_mid_impact	correlation	0.371	0.241	0.027
	p-value*	0.00791	0.0924	0.85

Appendix Table 69: Correlations between X factor and Performing Factors

1.11Time

		Club Head Speed at Impact	Horizontal Launch Angle	Handicap
t_swing_s	correlation	-0.243	-0.347	0.286
	p-value*	0.0886	0.0135	0.044
t_backswing_s	correlation	-0.199	-0.367	-0.164
	p-value*	0.165	0.00872	0.254
t_downswing_s	correlation	0.100	-0.193	-0.128
	p-value*	0.488	0.179	0.374

Appendix Table 70: Correlations between Time and Performing Factors

1.12 GRF

1.12.1 Right GRF

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
X_component				
ADDRESS	correlation	0.501	0.641	0.034
	p-value	<0.001	<0.001	0.816
EARLY BS	correlation	-0.415	-0.268	-0.367
	p-value	0.00274	0.0597	0.0087
LATE BS	correlation	-0.337	-0.306	-0.179
	p-value	0.0167	0.0304	0.213
INITIAL DS	correlation	0.179	-0.293	-0.233
	p-value	0.215	0.0388	0.104
IMPACT	correlation	0.249	0.370	0.177

	p-value	0.0806	0.00812	0.218
EARLY FT	correlation	-0.792	-0.453	-0.224
	p-value	<0.001	<0.001	0.118
FINISH	correlation	0.027	-0.082	-0.250
	p-value	0.855	0.57	0.0803
Y_component				
ADDRESS	correlation	-0.571	-0.346	0.266
	p-value	<0.001	0.0138	0.0617
EARLY BS	correlation	-0.472	-0.245	0.217
	p-value	<0.001	0.0858	0.13
LATE BS	correlation	-0.571	-0.186	-0.001
	p-value	<0.001	0.197	0.997
INITIAL DS	correlation	-0.274	0.122	-0.194
	p-value	0.0538	0.401	0.177
IMPACT	correlation	0.179	-0.011	0.202
	p-value	0.214	0.939	0.16
EARLY FT	correlation	0.567	0.587	0.439
	p-value	<0.001	<0.001	0.00143
FINISH	correlation	0.287	0.554	0.054
	p-value	0.043	<0.001	0.711
Z_component				
ADDRESS	correlation	0.827	0.516	0.347
	p-value	<0.001	<0.001	0.0135
EARLY BS	correlation	0.753	0.280	0.377
	p-value	<0.001	0.0488	0.00703
LATE BS	correlation	0.659	0.166	0.516
	p-value	<0.001	0.249	<0.001
INITIAL DS	correlation	0.205	-0.371	0.097
	p-value	0.154	0.00796	0.505
IMPACT	correlation	0.270	-0.065	0.114
	p-value	0.0583	0.651	0.432
EARLY FT	correlation	-0.024	-0.526	-0.285
	p-value	0.867	<0.001	0.0449
FINISH	correlation	0.277	-0.262	-0.081
	p-value	0.0514	0.0656	0.575

Appendix Table 71: Correlations between Right GRF and Performing Factors

1.12.2 Left GRF

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
X_component				
ADDRESS	correlation	-0.628	-0.399	0.052
	p-value	<0.001	0.00406	0.72
EARLY BS	correlation	-0.267	-0.338	0.100
	p-value	0.0606	0.0164	0.491
LATE BS	correlation	0.219	0.210	0.027
	p-value	0.127	0.143	0.854
INITIAL DS	correlation	-0.194	0.238	0.435
	p-value	0.177	0.0955	0.0016
IMPACT	correlation	0.282	0.295	0.228
	p-value	0.0469	0.0377	0.112
EARLY FT	correlation	-0.185	0.024	0.096
	p-value	0.198	0.87	0.509
FINISH	correlation	-0.120	0.054	0.259
	p-value	0.405	0.709	0.0698
Y_component				
ADDRESS	correlation	0.643	0.051	0.081
	p-value	<0.001	0.725	0.576
EARLY BS	correlation	-0.197	-0.158	-0.412
	p-value	0.169	0.273	0.00297
LATE BS	correlation	-0.067	0.004	-0.421
	p-value	0.642	0.975	0.0023
INITIAL DS	correlation	0.127	-0.218	-0.445
	p-value	0.38	0.129	0.00119
IMPACT	correlation	0.368	0.336	-0.413
	p-value	0.0085	0.0171	0.00284
EARLY FT	correlation	-0.103	0.058	-0.132
	p-value	0.478	0.687	0.359
FINISH	correlation	-0.346	-0.502	-0.177
	p-value	0.0139	<0.001	0.219
Z_component				
ADDRESS	correlation	0.321	-0.248	0.168
	p-value	0.0233	0.0823	0.244
EARLY BS	correlation	-0.314	-0.344	-0.191
	p-value	0.0265	0.0145	0.183
LATE BS	correlation	0.054	0.007	-0.454
	p-value	0.708	0.96	<0.001
INITIAL DS	correlation	0.627	0.300	0.169
	p-value	<0.001	0.034	0.241

IMPACT	correlation	0.469	0.567	0.090
	p-value	<0.001	<0.001	0.534
EARLY FT	correlation	-0.352	-0.288	0.229
	p-value	0.0123	0.0423	0.109
FINISH	correlation	0.425	0.311	0.343
	p-value	0.00209	0.0281	0.0147

Appendix Table 72: Correlations between Left GRF and Performing Factors

1.13 Ground Reaction Torques

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
ADDRESS	correlation	-0.490	-0.302	-0.641
	p-value	0.001	0.0251	<0.001
EARLY BS	correlation	0.145	-0.207	-0.288
	p-value	0.291	0.129	0.0429
LATE BS	correlation	0.295	0.050	-0.067
	p-value	0.0286	0.716	0.645
INITIAL DS	correlation	0.207	-0.011	-0.091
	p-value	0.13	0.936	0.529
IMPACT	correlation	-0.419	-0.392	-0.316
	p-value	0.00146	0.00312	0.0252
EARLY FT	correlation	0.288	0.531	0.051
	p-value	0.0331	0.001	0.727
FINISH	correlation	-0.387	-0.064	-0.360
	p-value	0.00349	0.641	0.010

Appendix Table 73: Correlations between GR Torques and Performing Factors

1.14 COP displacement

Position		Club Head Speed at impact	Horizontal Launch Angle	Handicap
X_component				
ADDRESS	correlation	-0.424	-0.023	-0.090
	p-value	0.00217	0.876	0.534
EARLY BS	correlation	-0.077	0.346	0.062
	p-value	0.595	0.0138	0.668
LATE BS	correlation	-0.117	0.335	0.042
	p-value	0.418	0.0174	0.775
INITIAL DS	correlation	-0.042	0.275	-0.219
	p-value	0.77	0.0533	0.126
IMPACT	correlation	0.161	0.435	0.161
	p-value	0.263	0.00161	0.265
EARLY FT	correlation	-0.142	0.111	0.125
	p-value	0.324	0.443	0.386
FINISH	correlation	0.261	0.549	0.218
	p-value	0.0667	<0.001	0.129
Y_component				
ADDRESS	correlation	0.318	0.430	0.120
	p-value	0.0245	0.00185	0.405
EARLY BS	correlation	0.476	0.326	0.312
	p-value	<0.001	0.0211	0.0273
LATE BS	correlation	0.290	0.052	0.660
	p-value	0.0412	0.72	<0.001
INITIAL DS	correlation	-0.124	-0.392	0.082
	p-value	0.39	0.00483	0.573
IMPACT	correlation	-0.200	-0.473	0.105
	p-value	0.164	<0.001	0.466
EARLY FT	correlation	0.243	0.087	-0.169
	p-value	0.0888	0.547	0.242
FINISH	correlation	0.241	-0.059	-0.231
	p-value	0.0924	0.681	0.107

Appendix Table 74: Correlations between COP Displacement and Performing Factors

2. Correlation between anthropometrical parameters and performance parameters

		Club Head Speed At Impact	Horizontal Launch Angle	Handicap
Body_Mass_kg	correlation	0.736	0.227	-0.108
	p-value*	<0.001	0.113	0.455
Body_height_cm	correlation	0.555	0.094	-0.067
	p-value*	<0.001	0.516	0.643
Crotch_height_cm	correlation	-0.019	-0.212	-0.241
	p-value*	0.895	0.139	0.0921
Knee_height_cm	correlation	0.143	-0.172	-0.216
	p-value*	0.321	0.232	0.132
Bust_chest_girth_horizontal_cm	correlation	0.674	0.369	-0.011
	p-value*	<0.001	0.00841	0.94
Arm_length_left_cm	correlation	0.405	0.065	0.300
	p-value*	0.00353	0.653	0.0344
Arm_length_right_cm	correlation	0.430	0.034	0.158
	p-value*	0.00185	0.817	0.273
Upper_arm_length_left_cm	correlation	0.413	-0.065	0.215
	p-value*	0.00289	0.653	0.135
Upper_arm_length_right_cm	correlation	0.286	-0.127	0.218
	p-value*	0.0443	0.38	0.129
Forearm_length_left_cm	correlation	0.157	0.301	0.345
	p-value*	0.275	0.0335	0.0143
Forearm_length_right_cm	correlation	0.475	0.144	0.084
	p-value*	<0.001	0.32	0.562
Upper_arm_girth_left_cm	correlation	0.716	0.208	-0.297
	p-value*	<0.001	0.147	0.0363
Upper_arm_girth_right_cm	correlation	0.619	0.128	-0.335
	p-value*	<0.001	0.377	0.0174
Forearm_girth_left_cm	correlation	0.755	0.266	-0.010
	p-value*	<0.001	0.0621	0.947
Forearm_girth_right_cm	correlation	0.782	0.278	-0.052
	p-value*	<0.001	0.0509	0.72
Thigh_girth_left_horizontal_cm	correlation	0.602	0.133	0.407
	p-value*	<0.001	0.358	0.00333
Thigh_girth_right_horizontal_cm	correlation	0.506	-0.056	0.248
	p-value*	<0.001	0.698	0.0821
Calf_girth_left_cm	correlation	0.540	0.188	0.412
	p-value*	<0.001	0.19	0.00297
Calf_girth_right_cm	correlation	0.401	0.084	0.385
	p-value*	0.00395	0.563	0.00583
Trochanter_belt_height_cm	correlation	0.452	-0.155	0.521
	p-value*	<0.001	0.282	<0.001
Biacromial_diameter_cm	correlation	0.763	0.356	0.040
	p-value*	<0.001	0.0111	0.781

Hand_length_right_cm	correlation	0.366	0.068	0.081
	p-value*	0.00888	0.639	0.578
Thigh_length_right_cm	correlation	0.518	0.126	-0.122
	p-value*	<0.001	0.382	0.4
Thigh_length_left_cm	correlation	0.327	-0.125	-0.242
	p-value*	0.0204	0.387	0.0898
Hand_palm_length_right_cm	correlation	0.431	-0.041	0.377
	p-value*	0.00176	0.777	0.00702
Hand_palm_length_left_cm	correlation	0.123	-0.109	-0.192
	p-value*	0.394	0.453	0.182
Leg_length_right_cm	correlation	0.272	-0.005	-0.091
	p-value*	0.0557	0.971	0.53
Ulnar_styloid_height_left_cm	correlation	0.421	-0.088	-0.040
	p-value*	0.00231	0.543	0.782
Trochanter_average_height_cm	correlation	0.333	-0.074	-0.186
	p-value*	0.0181	0.612	0.197
Trochanter_height_right_cm	correlation	0.396	0.014	-0.164
	p-value*	0.00436	0.923	0.256
Trochanter_height_left_cm	correlation	0.271	-0.150	-0.203
	p-value*	0.0565	0.297	0.157
Hand_width_right._cm	correlation	0.416	0.192	0.340
	p-value*	0.00268	0.182	0.0158
Foot_length_cm	correlation	-0.079	-0.057	0.262
	p-value*	0.587	0.695	0.0658

Appendix Table 75: Correlations between Anthropometrical Parameters and Performing Factors

		Club Head Speed At Impact	Horizontal Launch Angle	Handicap
Endomorphy	correlation	0.068	-0.107	0.007
	p-value*	0.637	0.459	0.96
Mesomorphy	correlation	0.567	0.298	-0.569
	p-value*	<0.001	0.0356	<0.001
Ectomorphy	correlation	-0.335	-0.289	-0.382
	p-value*	0.0174	0.0419	0.00612

Appendix Table 76: Correlations between Somatotype Parameters and Performing Factors

3. Correlation between anthropometrical parameters and biomechanical parameters

3.1 Ankle

3.1.1 Right Ankle Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body Height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	-0.468	-0.235	-0.038	0.419	0.123
	p-value	<0.001	0.101	0.791	0.00248	0.393
EARLY BS	correlation	-0.154	-0.048	0.001	0.330	0.412
	p-value	0.285	0.743	0.996	0.0192	0.00296
LATE BS	correlation	-0.145	-0.150	0.027	0.204	0.337
	p-value	0.316	0.297	0.855	0.155	0.0167
INITIAL DS	correlation	-0.029	-0.350	0.226	-0.086	-0.053
	p-value	0.842	0.0128	0.114	0.554	0.714
IMPACT	correlation	0.204	0.036	-0.196	-0.513	0.070
	p-value	0.156	0.804	0.172	<0.001	0.628
EARLY FT	correlation	0.145	-0.062	-0.011	-0.385	-0.004
	p-value	0.314	0.67	0.942	0.00581	0.978
FINISH	correlation	-0.088	0.050	0.105	0.033	-0.011
	p-value	0.542	0.73	0.468	0.822	0.937
ABDUCTION -ADDUCTION						
ADDRESS	correlation	-0.390	0.022	0.513	0.153	-0.276
	p-value	0.00512	0.879	<0.001	0.288	0.0525
EARLY BS	correlation	-0.415	0.119	0.697	0.101	-0.470
	p-value	0.00273	0.411	<0.001	0.486	<0.001
LATE BS	correlation	-0.490	0.040	0.775	0.082	-0.599
	p-value	<0.001	0.781	<0.001	0.571	<0.001
INITIAL DS	correlation	-0.422	0.061	0.782	0.130	-0.611
	p-value	0.00227	0.675	<0.001	0.367	<0.001
IMPACT	correlation	-0.191	0.146	0.040	-0.215	-0.155
	p-value	0.185	0.312	0.785	0.134	0.282
EARLY FT	correlation	-0.044	0.041	0.195	-0.166	-0.207
	p-value	0.764	0.778	0.175	0.249	0.149
FINISH	correlation	0.025	-0.071	0.053	0.116	0.118
	p-value	0.861	0.623	0.714	0.423	0.414
EXTERNAL – INTERNAL ROTATION						
ADDRESS	correlation	-0.641	-0.106	0.680	0.193	-0.734
	p-value	<0.001	0.465	<0.001	0.179	<0.001
EARLY BS	correlation	-0.625	-0.076	0.585	0.183	-0.761

	p-value	<0.001	0.599	<0.001	0.204	<0.001
LATE BS	correlation	-0.533	-0.010	0.469	0.210	-0.691
	p-value	<0.001	0.946	<0.001	0.144	<0.001
INITIAL DS	correlation	-0.496	-0.010	0.339	0.142	-0.638
	p-value	<0.001	0.942	0.0162	0.325	<0.001
IMPACT	correlation	-0.618	0.139	0.450	0.289	-0.383
	p-value	<0.001	0.335	0.00104	0.0416	0.00602
EARLY FT	correlation	-0.545	0.107	0.415	0.286	-0.276
	p-value	<0.001	0.461	0.00271	0.0442	0.0525
FINISH	correlation	-0.396	0.210	0.567	0.446	0.016
	p-value	0.00445	0.143	<0.001	0.00117	0.915

Appendix Table 77: Correlations between Right Ankle Angle and Anthropometrical Factors

3.1.2 Left Ankle Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body Height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	0.258	0.066	-0.200	0.937	0.00187
	p-value	0.0707	0.647	0.164	0.164	0.549
EARLY BS	correlation	-0.020	0.177	0.171	0.256	<0.001
	p-value	0.893	0.218	0.234	-0.056	0.308
LATE BS	correlation	-0.030	0.044	0.223	0.698	0.0296
	p-value	0.834	0.76	0.12	-0.171	0.079
INITIAL DS	correlation	-0.113	-0.050	0.226	0.236	0.587
	p-value	0.433	0.729	0.115	-0.526	0.302
IMPACT	correlation	0.204	0.007	-0.592	<0.001	0.0333
	p-value	0.156	0.96	<0.001	-0.431	0.347
EARLY FT	correlation	0.248	0.041	-0.618	0.00177	0.0137
	p-value	0.0821	0.776	<0.001	-0.476	-0.161
FINISH	correlation	0.138	-0.094	-0.417	<0.001	0.263
	p-value	0.34	0.518	0.00262	0.937	0.00187
ABDUCTION -ADDUCTION						
ADDRESS	correlation	-0.400	0.410	0.398	0.662	0.493
	p-value	0.00404	0.00312	0.00418	<0.001	<0.001
EARLY BS	correlation	-0.239	0.197	0.295	0.363	0.515
	p-value	0.0951	0.17	0.0375	0.00951	<0.001
LATE BS	correlation	-0.377	0.006	0.322	0.301	0.325
	p-value	0.00697	0.968	0.0225	0.0334	0.0214
INITIAL DS	correlation	-0.526	-0.078	0.379	0.158	-0.017
	p-value	<0.001	0.589	0.0066	0.273	0.904
IMPACT	correlation	-0.228	0.340	0.627	0.374	0.264
	p-value	0.111	0.0157	<0.001	0.00745	0.0643
EARLY FT	correlation	-0.106	0.452	0.429	0.414	0.487

	p-value	0.463	<0.001	0.00186	0.00283	<0.001
FINISH	correlation	0.478	-0.008	-0.124	-0.025	0.426
	p-value	<0.001	0.954	0.391	0.864	0.00201
EXTERNAL – INTERNAL ROTATION						
ADDRESS	correlation	-0.650	-0.338	0.505	0.383	-0.513
	p-value	<0.001	0.0164	<0.001	0.0061	<0.001
EARLY BS	correlation	-0.515	-0.382	0.301	0.366	-0.398
	p-value	<0.001	0.00621	0.0336	0.009	0.00416
LATE BS	correlation	-0.399	-0.281	0.175	0.463	-0.222
	p-value	0.00412	0.0477	0.224	<0.001	0.121
INITIAL DS	correlation	-0.330	-0.262	0.098	0.464	-0.123
	p-value	0.0194	0.0665	0.5	<0.001	0.393
IMPACT	correlation	-0.405	-0.181	0.570	0.101	-0.715
	p-value	0.00352	0.209	<0.001	0.485	<0.001
EARLY FT	correlation	-0.249	-0.137	0.362	-0.019	-0.588
	p-value	0.0814	0.343	0.00987	0.896	<0.001
FINISH	correlation	-0.407	-0.336	0.320	0.193	-0.474
	p-value	0.00338	0.0172	0.0234	0.18	<0.001

Appendix Table 78: Correlations between Left Ankle Angle and Anthropometrical Factors

3.1.3 Ankle Angular Velocity

Position		Endomorphy	Mesomorphy	Ectomorphy	Body Height	Body Mass
RIGHT						
ADDRESS	correlation	-0.130	0.225	-0.087	0.131	0.115
	p-value	0.37	0.117	0.55	0.363	0.425
EARLY BS	correlation	0.173	0.123	-0.474	-0.195	0.165
	p-value	0.229	0.395	<0.001	0.174	0.251
LATE BS	correlation	0.131	-0.354	-0.409	-0.402	-0.051
	p-value	0.364	0.0117	0.00322	0.00381	0.724
INITIAL DS	correlation	-0.176	-0.309	-0.009	-0.308	-0.326
	p-value	0.22	0.0288	0.95	0.0296	0.0209
IMPACT	correlation	0.054	0.258	-0.214	-0.148	-0.020
	p-value	0.708	0.0706	0.136	0.306	0.892
EARLY FT	correlation	0.015	0.215	-0.283	0.155	0.297
	p-value	0.918	0.133	0.0465	0.283	0.0361
FINISH	correlation	0.036	0.128	0.136	-0.122	0.021
	p-value	0.805	0.374	0.347	0.399	0.884
LEFT						
ADDRESS	correlation	0.438	-0.058	-0.460	-0.138	0.127
	p-value	0.00147	0.687	<0.001	0.34	0.379
EARLY BS	correlation	-0.015	-0.130	-0.035	-0.269	-0.032
	p-value	0.919	0.369	0.807	0.0588	0.826

LATE BS	correlation	0.436	0.050	-0.346	-0.346	0.327
	p-value	0.00157	0.733	0.0138	0.014	0.0206
INITIAL DS	correlation	0.039	0.240	0.058	0.260	0.170
	p-value	0.786	0.0935	0.691	0.0682	0.237
IMPACT	correlation	-0.159	0.176	0.330	0.045	-0.040
	p-value	0.269	0.222	0.0191	0.755	0.78
EARLY FT	correlation	-0.240	0.136	0.602	0.493	-0.257
	p-value	0.0933	0.346	<0.001	<0.001	0.0713
FINISH	correlation	0.350	0.026	-0.372	-0.099	0.431
	p-value	0.0127	0.856	0.00776	0.495	0.00177

Appendix Table 79: Correlations between Ankle Angular Velocity and Anthropometrical Factors

3.1.4 Right Ankle Torque

Position		Endomorphy	Mesomorphy	Ectomorphy	Body Height	Body Mass
X_component						
ADDRESS	correlation	0.263	-0.510	-0.014	-0.422	-0.268
	p-value	0.0648	<0.001	0.925	0.00229	0.0597
EARLY BS	correlation	0.289	-0.033	-0.325	-0.548	-0.354
	p-value	0.0415	0.818	0.0213	<0.001	0.0118
LATE BS	correlation	0.017	-0.142	-0.095	-0.555	-0.506
	p-value	0.906	0.327	0.512	<0.001	<0.001
INITIAL DS	correlation	0.301	-0.007	-0.250	-0.600	-0.299
	p-value	0.0335	0.963	0.0797	<0.001	0.0347
IMPACT	correlation	0.021	-0.167	-0.256	0.179	-0.008
	p-value	0.886	0.246	0.0724	0.214	0.955
EARLY FT	correlation	-0.052	-0.256	-0.459	-0.116	-0.038
	p-value	0.718	0.0728	<0.001	0.422	0.794
FINISH	correlation	-0.316	-0.005	-0.018	0.258	0.011
	p-value	0.0253	0.972	0.9	0.071	0.94
Y_component						
ADDRESS	correlation	0.347	-0.144	-0.067	-0.341	0.024
	p-value	0.0135	0.318	0.641	0.0154	0.869
EARLY BS	correlation	0.354	-0.099	-0.615	-0.537	0.137
	p-value	0.0118	0.493	<0.001	<0.001	0.341
LATE BS	correlation	0.201	-0.329	-0.328	-0.665	-0.192
	p-value	0.162	0.0197	0.0201	<0.001	0.181
INITIAL DS	correlation	0.079	-0.193	-0.041	-0.374	0.099
	p-value	0.585	0.18	0.777	0.00745	0.493
IMPACT	correlation	0.423	-0.288	-0.356	-0.190	0.278
	p-value	0.00221	0.0426	0.0111	0.186	0.0508
EARLY FT	correlation	0.330	-0.069	-0.573	-0.186	0.290
	p-value	0.0193	0.633	<0.001	0.196	0.041

FINISH	correlation	0.130	-0.144	-0.374	-0.216	0.034
	p-value	0.367	0.317	0.00749	0.131	0.816
Z_component						
ADDRESS	correlation	0.062	-0.424	0.172	-0.293	-0.586
	p-value	0.67	0.00217	0.232	0.0387	<0.001
EARLY BS	correlation	0.036	-0.085	0.103	-0.409	-0.649
	p-value	0.802	0.555	0.477	0.00322	<0.001
LATE BS	correlation	-0.045	-0.015	0.323	-0.300	-0.668
	p-value	0.758	0.92	0.0221	0.034	<0.001
INITIAL DS	correlation	-0.075	0.177	0.359	-0.147	-0.555
	p-value	0.603	0.218	0.0106	0.307	<0.001
IMPACT	correlation	0.015	0.071	0.346	0.287	-0.048
	p-value	0.917	0.623	0.0139	0.0431	0.74
EARLY FT	correlation	0.408	-0.085	-0.719	-0.229	0.231
	p-value	0.0033	0.558	<0.001	0.11	0.107
FINISH	correlation	0.407	0.165	-0.302	-0.153	0.090
	p-value	0.00339	0.254	0.0333	0.288	0.533

Appendix Table 80: Correlations between Right Ankle Torque and Anthropometrical Factors

3.1.5 Left Ankle Torque

Position		Endomorphy	Mesomorphy	Ectomorphy	Body Height	Body Mass
X_component						
ADDRESS	correlation	0.407	0.145	0.045	-0.326	-0.116
	p-value	0.00339	0.314	0.755	0.021	0.422
EARLY BS	correlation	0.253	-0.069	-0.489	-0.336	0.354
	p-value	0.0765	0.632	<0.001	0.017	0.0117
LATE BS	correlation	0.365	-0.093	-0.647	-0.282	0.460
	p-value	0.00914	0.521	<0.001	0.0476	<0.001
INITIAL DS	correlation	0.554	0.560	-0.393	0.087	0.584
	p-value	<0.001	<0.001	0.0047	0.546	<0.001
IMPACT	correlation	-0.176	-0.481	-0.181	0.232	0.106
	p-value	0.221	<0.001	0.21	0.104	0.465
EARLY FT	correlation	0.002	-0.404	-0.481	-0.146	0.252
	p-value	0.988	0.00365	<0.001	0.31	0.078
FINISH	correlation	0.392	0.194	-0.131	-0.136	0.313
	p-value	0.00485	0.178	0.366	0.346	0.0268
Y_component						
ADDRESS	correlation	0.441	0.226	-0.515	-0.307	0.464
	p-value	0.00136	0.115	<0.001	0.0299	<0.001
EARLY BS	correlation	0.038	-0.029	-0.101	-0.108	0.160
	p-value	0.792	0.84	0.485	0.456	0.266
LATE BS	correlation	0.171	-0.106	-0.316	-0.178	0.227

	p-value	0.234	0.465	0.0256	0.215	0.113
INITIAL DS	correlation	0.514	0.166	-0.766	-0.422	0.234
	p-value	<0.001	0.248	<0.001	0.00225	0.102
IMPACT	correlation	0.778	0.028	-0.756	-0.373	0.397
	p-value	<0.001	0.845	<0.001	0.00763	0.00431
EARLY FT	correlation	0.237	0.072	0.313	-0.082	-0.396
	p-value	0.0979	0.619	0.0268	0.573	0.00447
FINISH	correlation	-0.446	-0.243	0.395	0.031	-0.400
	p-value	0.00117	0.0887	0.00452	0.83	0.004
Z_component						
ADDRESS	correlation	0.493	0.296	-0.209	-0.470	0.082
	p-value	<0.001	0.0366	0.145	<0.001	0.571
EARLY BS	correlation	0.423	-0.035	-0.503	-0.265	0.160
	p-value	0.00222	0.809	<0.001	0.0626	0.266
LATE BS	correlation	0.589	-0.155	-0.596	-0.148	0.188
	p-value	<0.001	0.284	<0.001	0.306	0.192
INITIAL DS	correlation	-0.017	-0.468	-0.076	-0.289	-0.474
	p-value	0.907	<0.001	0.6	0.0421	<0.001
IMPACT	correlation	0.241	-0.083	-0.694	-0.245	0.097
	p-value	0.0912	0.566	<0.001	0.0867	0.502
EARLY FT	correlation	0.478	-0.364	-0.477	-0.484	0.017
	p-value	<0.001	0.00929	<0.001	<0.001	0.907
FINISH	correlation	-0.419	-0.004	0.344	0.127	-0.208
	p-value	0.00246	0.977	0.0143	0.38	0.147

Appendix Table 81: Correlations between Left Ankle Torque and Anthropometrical Factors

3.2 Knee

3.2.1 Right Knee Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	-0.468	-0.283	0.027	0.469	0.064
	p-value	<0.001	0.0463	0.85	<0.001	0.66
EARLY BS	correlation	-0.277	-0.096	0.010	0.420	0.503
	p-value	0.0514	0.507	0.944	0.00241	<0.001
LATE BS	correlation	-0.218	-0.111	-0.079	0.265	0.511
	p-value	0.129	0.445	0.584	0.0627	<0.001
INITIAL DS	correlation	-0.157	-0.290	-0.050	-0.060	0.233
	p-value	0.277	0.0411	0.728	0.68	0.103
IMPACT	correlation	-0.410	0.106	0.201	0.284	0.299
	p-value	0.00314	0.465	0.162	0.0454	0.035

EARLY FT	correlation	-0.272	-0.045	0.305	0.382	0.329
	p-value	0.0562	0.756	0.0313	0.00619	0.0198
FINISH	correlation	-0.048	-0.017	-0.032	0.258	0.056
	p-value	0.739	0.907	0.826	0.0701	0.699
EXTERNAL – INTERNAL ROTATION						
ADDRESS	correlation	-0.010	-0.086	-0.180	-0.123	-0.525
	p-value	0.946	0.555	0.211	0.394	<0.001
EARLY BS	correlation	-0.207	-0.159	0.065	-0.074	-0.689
	p-value	0.149	0.27	0.656	0.61	<0.001
LATE BS	correlation	-0.186	-0.130	0.057	0.013	-0.629
	p-value	0.197	0.367	0.695	0.931	<0.001
INITIAL DS	correlation	-0.317	-0.230	-0.010	0.068	-0.541
	p-value	0.0247	0.108	0.943	0.639	<0.001
IMPACT	correlation	-0.104	-0.399	-0.047	-0.344	-0.749
	p-value	0.471	0.00405	0.746	0.0144	<0.001
EARLY FT	correlation	-0.057	-0.303	-0.338	-0.112	-0.342
	p-value	0.693	0.0324	0.0164	0.44	0.0149
FINISH	correlation	0.405	0.058	-0.282	-0.449	-0.326
	p-value	0.00352	0.69	0.0472	0.00107	0.0208

Appendix Table 82: Correlations between Right Knee Angle and Anthropometrical Factors

3.2.2 Left Knee Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	0.144	-0.489	-0.043	0.046	0.045
	p-value	0.317	<0.001	0.765	0.749	0.756
EARLY BS	correlation	-0.167	-0.087	0.277	0.274	0.380
	p-value	0.246	0.548	0.0515	0.0541	0.00642
LATE BS	correlation	-0.147	-0.144	0.271	0.096	0.232
	p-value	0.307	0.32	0.057	0.509	0.105
INITIAL DS	correlation	-0.348	-0.200	0.271	0.084	0.100
	p-value	0.0133	0.164	0.0573	0.561	0.49
IMPACT	correlation	0.422	0.032	-0.703	-0.484	0.373
	p-value	0.00225	0.823	<0.001	<0.001	0.00762
EARLY FT	correlation	0.209	-0.334	-0.404	-0.502	-0.001
	p-value	0.145	0.0177	0.00359	<0.001	0.997
FINISH	correlation	0.664	-0.438	-0.593	-0.560	-0.088
	p-value	<0.001	0.00145	<0.001	<0.001	0.545
EXTERNAL – INTERNAL ROTATION						
ADDRESS	correlation	-0.407	0.032	0.374	0.197	-0.638

	p-value	0.00335	0.823	0.00752	0.17	<0.001
EARLY BS	correlation	-0.156	-0.146	0.164	-0.207	-0.715
	p-value	0.278	0.31	0.255	0.149	<0.001
LATE BS	correlation	-0.030	-0.168	0.084	-0.358	-0.679
	p-value	0.834	0.242	0.564	0.0107	<0.001
INITIAL DS	correlation	-0.062	-0.019	-0.004	-0.249	-0.603
	p-value	0.671	0.897	0.977	0.0814	<0.001
IMPACT	correlation	-0.446	-0.277	0.406	0.307	-0.569
	p-value	0.00116	0.0517	0.00346	0.0303	<0.001
EARLY FT	correlation	-0.500	-0.340	0.201	0.222	-0.535
	p-value	<0.001	0.0158	0.162	0.121	<0.001
FINISH	correlation	-0.557	-0.011	0.375	0.297	-0.368
	p-value	<0.001	0.942	0.00721	0.0363	0.0085

Appendix Table 83: Correlations between Left Knee Angle and Anthropometrical Factors

3.2.3 Knee Angular Velocity

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
RIGHT						
ADDRESS	correlation	-0.085	-0.127	-0.031	0.277	0.335
	p-value	0.559	0.381	0.833	0.0518	0.0174
EARLY BS	correlation	0.302	0.270	-0.390	-0.080	0.258
	p-value	0.0332	0.0582	0.00515	0.58	0.0705
LATE BS	correlation	0.187	-0.236	-0.204	-0.495	-0.309
	p-value	0.194	0.099	0.155	<0.001	0.0291
INITIAL DS	correlation	-0.340	-0.489	0.104	-0.463	-0.566
	p-value	0.0156	<0.001	0.474	<0.001	<0.001
IMPACT	correlation	-0.289	0.143	-0.143	0.141	-0.078
	p-value	0.044	0.325	0.326	0.335	0.594
EARLY FT	correlation	-0.255	0.237	0.018	0.279	0.143
	p-value	0.0767	0.101	0.905	0.0525	0.327
FINISH	correlation	0.010	0.008	-0.129	-0.100	0.119
	p-value	0.946	0.954	0.371	0.49	0.41
LEFT						
ADDRESS	correlation	0.410	-0.418	-0.314	-0.537	-0.345
	p-value	0.00307	0.00253	0.0264	<0.001	0.0143
EARLY BS	correlation	0.102	0.102	-0.136	-0.231	0.124
	p-value	0.483	0.482	0.346	0.107	0.39
LATE BS	correlation	0.123	0.050	-0.417	-0.343	0.077
	p-value	0.394	0.729	0.0026	0.0147	0.594
INITIAL DS	correlation	-0.310	-0.281	0.066	-0.084	-0.337

	p-value	0.0282	0.0485	0.649	0.562	0.0168
IMPACT	correlation	0.238	0.079	-0.560	-0.225	0.487
	p-value	0.1	0.589	<0.001	0.119	<0.001
EARLY FT	correlation	-0.183	0.164	0.133	-0.149	-0.364
	p-value	0.209	0.261	0.364	0.308	0.0101
FINISH	correlation	0.251	0.244	-0.294	-0.034	0.393
	p-value	0.0784	0.0872	0.038	0.814	0.00473

Appendix Table 84: Correlations between Knee Angular Velocity and Anthropometrical Factors

3.2.4 Right Knee Torque

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
X_component						
ADDRESS	correlation	-0.434	-0.322	-0.265	0.206	0.045
	p-value	0.00165	0.0224	0.0626	0.151	0.754
EARLY BS	correlation	0.022	-0.011	-0.546	-0.165	0.469
	p-value	0.88	0.94	<0.001	0.253	<0.001
LATE BS	correlation	-0.172	-0.187	-0.275	-0.296	0.194
	p-value	0.232	0.195	0.0535	0.0369	0.177
INITIAL DS	correlation	0.230	0.428	-0.008	0.112	0.648
	p-value	0.107	0.00191	0.955	0.438	<0.001
IMPACT	correlation	-0.292	0.150	0.059	0.474	0.527
	p-value	0.0397	0.299	0.686	<0.001	<0.001
EARLY FT	correlation	-0.025	-0.153	0.138	-0.096	0.067
	p-value	0.863	0.29	0.338	0.508	0.643
FINISH	correlation	0.218	0.142	-0.379	0.059	0.259
	p-value	0.128	0.324	0.00665	0.682	0.0695
Y_component						
ADDRESS	correlation	-0.030	-0.206	-0.121	0.157	-0.166
	p-value	0.837	0.152	0.403	0.278	0.25
EARLY BS	correlation	-0.153	-0.101	0.457	0.010	-0.644
	p-value	0.288	0.484	<0.001	0.944	<0.001
LATE BS	correlation	-0.107	-0.118	0.557	-0.087	-0.712
	p-value	0.458	0.415	<0.001	0.549	<0.001
INITIAL DS	correlation	-0.596	0.142	0.846	0.284	-0.508
	p-value	<0.001	0.324	<0.001	0.0456	<0.001
IMPACT	correlation	-0.575	0.189	0.539	0.570	0.003
	p-value	<0.001	0.189	<0.001	<0.001	0.982
EARLY FT	correlation	0.263	-0.032	-0.010	0.270	0.281
	p-value	0.0654	0.827	0.943	0.0581	0.0483
FINISH	correlation	0.173	0.036	0.248	-0.143	-0.061
	p-value	0.23	0.804	0.0827	0.322	0.673
Z_component						

ADDRESS	correlation	0.014	-0.095	0.029	-0.026	-0.444
	p-value	0.925	0.511	0.843	0.859	0.00122
EARLY BS	correlation	-0.313	-0.170	0.534	0.052	-0.819
	p-value	0.027	0.239	<0.001	0.719	<0.001
LATE BS	correlation	-0.229	0.044	0.632	0.208	-0.665
	p-value	0.109	0.762	<0.001	0.147	<0.001
INITIAL DS	correlation	-0.339	-0.001	0.484	0.315	-0.556
	p-value	0.0162	0.996	<0.001	0.0259	<0.001
IMPACT	correlation	-0.488	0.233	0.181	0.749	0.335
	p-value	<0.001	0.104	0.208	<0.001	0.0174
EARLY FT	correlation	0.221	-0.085	-0.287	0.195	0.345
	p-value	0.123	0.559	0.0433	0.174	0.0141
FINISH	correlation	0.238	0.005	0.103	-0.170	0.090
	p-value	0.0957	0.975	0.478	0.237	0.532

Appendix Table 85: Correlations between Right Knee Torque and Anthropometrical Factors

3.2.5 Left Knee Torque

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
X_component						
ADDRESS	correlation	0.300	0.221	-0.250	-0.329	0.295
	p-value	0.0345	0.123	0.0793	0.0195	0.0375
EARLY BS	correlation	-0.500	0.325	0.566	0.203	-0.147
	p-value	<0.001	0.0213	<0.001	0.157	0.307
LATE BS	correlation	-0.612	0.495	0.461	0.283	-0.143
	p-value	<0.001	<0.001	<0.001	0.0464	0.321
INITIAL DS	correlation	0.019	0.154	-0.208	-0.081	-0.076
	p-value	0.896	0.286	0.147	0.575	0.601
IMPACT	correlation	0.067	0.016	-0.665	0.043	0.562
	p-value	0.642	0.912	<0.001	0.768	<0.001
EARLY FT	correlation	-0.131	-0.195	-0.365	0.016	0.181
	p-value	0.364	0.175	0.00915	0.911	0.209
FINISH	correlation	0.271	0.457	-0.412	-0.032	0.297
	p-value	0.0566	<0.001	0.00297	0.828	0.0359
Y_component						
ADDRESS	correlation	-0.091	0.095	0.129	0.131	-0.376
	p-value	0.532	0.514	0.371	0.364	0.0072
EARLY BS	correlation	0.009	0.036	0.270	0.168	-0.343
	p-value	0.95	0.802	0.0581	0.244	0.0147
LATE BS	correlation	-0.352	0.076	0.482	-0.049	-0.604
	p-value	0.0123	0.6	<0.001	0.737	<0.001
INITIAL DS	correlation	-0.327	-0.602	-0.045	-0.532	-0.635
	p-value	0.0204	<0.001	0.755	<0.001	<0.001

IMPACT	correlation	0.037	-0.656	-0.000	-0.205	-0.389
	p-value	0.796	<0.001	1	0.153	0.00519
EARLY FT	correlation	-0.142	0.053	0.434	0.133	-0.415
	p-value	0.326	0.714	0.00164	0.356	0.00271
FINISH	correlation	-0.318	-0.140	0.530	0.080	-0.202
	p-value	0.0243	0.332	<0.001	0.581	0.16
Z_component						
ADDRESS	correlation	0.554	-0.054	-0.375	-0.377	0.375
	p-value	<0.001	0.709	0.00729	0.00698	0.00729
EARLY BS	correlation	0.547	-0.151	-0.444	-0.189	0.264
	p-value	<0.001	0.297	0.00122	0.189	0.0634
LATE BS	correlation	0.082	-0.105	0.152	0.093	-0.136
	p-value	0.569	0.467	0.291	0.521	0.345
INITIAL DS	correlation	-0.148	-0.708	-0.005	-0.318	-0.472
	p-value	0.307	<0.001	0.972	0.0245	<0.001
IMPACT	correlation	-0.097	-0.429	0.431	-0.198	-0.700
	p-value	0.504	0.00186	0.00177	0.168	<0.001
EARLY FT	correlation	0.170	-0.197	0.026	-0.268	-0.367
	p-value	0.239	0.171	0.859	0.0598	0.00871
FINISH	correlation	-0.231	-0.529	0.300	-0.151	-0.378
	p-value	0.106	<0.001	0.034	0.294	0.00674

Appendix Table 86: Correlations between Left Knee Torque and Anthropometrical Factors

3.3 Hip

3.3.1 Right Hip Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	0.031	0.233	-0.021	-0.081	-0.132
	p-value	0.83	0.103	0.886	0.576	0.36
EARLY BS	correlation	0.003	-0.018	0.101	-0.251	-0.534
	p-value	0.984	0.9	0.485	0.0787	<0.001
LATE BS	correlation	0.033	-0.058	0.122	-0.221	-0.543
	p-value	0.818	0.688	0.398	0.123	<0.001
INITIAL DS	correlation	0.078	-0.051	0.134	-0.063	-0.340
	p-value	0.591	0.724	0.353	0.664	0.0159
IMPACT	correlation	0.146	0.100	0.288	0.170	-0.276
	p-value	0.313	0.491	0.0425	0.238	0.0527
EARLY FT	correlation	0.084	0.141	0.302	0.353	-0.144
	p-value	0.56	0.328	0.0331	0.0119	0.32
FINISH	correlation	-0.014	-0.404	0.306	-0.285	-0.405

	p-value	0.926	0.00366	0.0307	0.0452	0.00354
ABDUCTION -ADDUCTION						
ADDRESS	correlation	0.173	0.208	-0.093	0.405	0.157
	p-value	0.229	0.148	0.522	0.00357	0.277
EARLY BS	correlation	0.153	0.051	-0.018	-0.161	-0.512
	p-value	0.287	0.723	0.901	0.263	<0.001
LATE BS	correlation	0.072	0.008	0.041	-0.199	-0.626
	p-value	0.62	0.954	0.777	0.166	<0.001
INITIAL DS	correlation	0.001	0.181	0.079	0.129	-0.408
	p-value	0.994	0.208	0.587	0.372	0.00327
IMPACT	correlation	-0.682	0.489	0.602	0.699	0.030
	p-value	<0.001	<0.001	<0.001	<0.001	0.836
EARLY FT	correlation	-0.672	0.475	0.676	0.605	-0.045
	p-value	<0.001	<0.001	<0.001	<0.001	0.756
FINISH	correlation	-0.279	0.307	0.207	0.192	-0.082
	p-value	0.0495	0.0303	0.149	0.181	0.57
EXTERNAL – INTERNAL ROTATION						
ADDRESS	correlation	-0.345	-0.231	0.370	-0.237	-0.394
	p-value	0.0141	0.107	0.00826	0.0979	0.00469
EARLY BS	correlation	-0.152	-0.057	0.093	-0.187	-0.304
	p-value	0.293	0.695	0.519	0.192	0.0318
LATE BS	correlation	-0.151	0.047	-0.102	0.070	-0.035
	p-value	0.295	0.748	0.479	0.627	0.811
INITIAL DS	correlation	-0.241	-0.021	0.039	0.137	-0.106
	p-value	0.0925	0.887	0.786	0.342	0.463
IMPACT	correlation	0.021	0.229	0.423	0.010	-0.233
	p-value	0.885	0.11	0.00219	0.945	0.104
EARLY FT	correlation	0.089	-0.100	0.268	-0.479	-0.448
	p-value	0.539	0.49	0.06	<0.001	0.00112
FINISH	correlation	0.004	0.158	0.520	-0.066	-0.339
	p-value	0.977	0.274	<0.001	0.648	0.0159

Appendix Table 87: Correlations between Right Hip Angle and Anthropometrical Factors

3.3.2 Left Hip Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	-0.253	0.280	-0.068	0.126	-0.067
	p-value	0.0759	0.0485	0.639	0.382	0.642
EARLY BS	correlation	0.028	0.032	-0.164	-0.202	-0.311
	p-value	0.847	0.826	0.254	0.159	0.0277

LATE BS	correlation	0.113	-0.048	-0.161	-0.295	-0.347
	p-value	0.435	0.74	0.265	0.0372	0.0134
INITIAL DS	correlation	0.328	-0.022	-0.201	-0.324	-0.253
	p-value	0.02	0.881	0.162	0.0216	0.0769
IMPACT	correlation	-0.371	0.177	0.632	0.609	-0.074
	p-value	0.00796	0.22	<0.001	<0.001	0.61
EARLY FT	correlation	-0.223	0.349	0.433	0.665	0.193
	p-value	0.119	0.0131	0.00168	<0.001	0.179
FINISH	correlation	-0.505	0.017	0.597	0.293	-0.300
	p-value	<0.001	0.909	<0.001	0.039	0.034
ABDUCTION -ADDUCTION						
ADDRESS	correlation	0.137	-0.130	-0.445	-0.353	-0.329
	p-value	0.341	0.368	0.00121	0.0119	0.0195
EARLY BS	correlation	-0.277	-0.057	0.049	0.428	0.502
	p-value	0.0512	0.697	0.737	0.00193	<0.001
LATE BS	correlation	-0.322	-0.010	0.094	0.510	0.545
	p-value	0.0225	0.944	0.517	<0.001	<0.001
INITIAL DS	correlation	-0.411	-0.138	0.172	0.319	0.372
	p-value	0.00304	0.338	0.232	0.0237	0.00774
IMPACT	correlation	0.368	-0.051	-0.533	-0.444	0.130
	p-value	0.00854	0.723	<0.001	0.00125	0.368
EARLY FT	correlation	0.390	0.012	-0.548	-0.350	0.196
	p-value	0.00509	0.932	<0.001	0.0128	0.173
FINISH	correlation	0.223	0.697	-0.432	0.326	0.621
	p-value	0.12	<0.001	0.00175	0.021	<0.001
EXTERNAL – INTERNAL ROTATION						
ADDRESS	correlation	-0.379	-0.262	0.568	0.056	-0.115
	p-value	0.00671	0.066	<0.001	0.7	0.427
EARLY BS	correlation	-0.467	-0.165	0.551	0.293	-0.021
	p-value	<0.001	0.251	<0.001	0.0387	0.885
LATE BS	correlation	-0.491	-0.081	0.619	0.378	-0.064
	p-value	<0.001	0.578	<0.001	0.00684	0.657
INITIAL DS	correlation	-0.154	0.030	0.541	0.293	0.045
	p-value	0.286	0.837	<0.001	0.0392	0.757
IMPACT	correlation	-0.186	-0.134	0.413	0.345	0.091
	p-value	0.195	0.353	0.00288	0.014	0.531
EARLY FT	correlation	-0.346	0.053	0.695	0.474	-0.067
	p-value	0.0139	0.716	<0.001	<0.001	0.646
FINISH	correlation	0.303	-0.223	-0.287	-0.399	-0.151
	p-value	0.0327	0.12	0.0429	0.00414	0.297

Appendix Table 88: Correlations between Left Hip Angle and Anthropometrical Factors

3.3.3 Hip Angular Velocity

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
RIGHT						
ADDRESS	correlation	-0.345	-0.253	0.021	-0.014	-0.072
	p-value	0.0141	0.0767	0.886	0.921	0.62
EARLY BS	correlation	0.095	-0.322	0.027	-0.280	0.008
	p-value	0.515	0.0241	0.851	0.0517	0.957
LATE BS	correlation	0.289	-0.224	-0.240	-0.633	-0.106
	p-value	0.0418	0.118	0.0927	<0.001	0.463
INITIAL DS	correlation	-0.151	-0.512	-0.283	-0.448	-0.288
	p-value	0.294	<0.001	0.0466	0.00112	0.0425
IMPACT	correlation	-0.531	0.187	0.115	0.270	0.044
	p-value	<0.001	0.198	0.433	0.0608	0.762
EARLY FT	correlation	-0.371	-0.210	0.096	0.140	0.107
	p-value	0.0087	0.147	0.51	0.338	0.466
FINISH	correlation	0.033	-0.029	0.062	-0.151	0.030
	p-value	0.82	0.843	0.668	0.296	0.837
LEFT						
ADDRESS	correlation	0.069	-0.329	-0.435	-0.249	-0.186
	p-value	0.634	0.0198	0.0016	0.0818	0.197
EARLY BS	correlation	0.290	0.009	-0.385	-0.032	0.271
	p-value	0.0409	0.953	0.0058	0.827	0.0571
LATE BS	correlation	0.379	0.102	-0.468	-0.179	0.316
	p-value	0.00672	0.483	<0.001	0.214	0.0253
INITIAL DS	correlation	-0.610	-0.549	0.208	-0.269	-0.570
	p-value	<0.001	<0.001	0.148	0.0584	<0.001
IMPACT	correlation	0.263	0.232	-0.221	-0.148	0.010
	p-value	0.0645	0.104	0.123	0.306	0.942
EARLY FT	correlation	0.156	-0.003	-0.577	-0.251	0.081
	p-value	0.279	0.981	<0.001	0.0784	0.577
FINISH	correlation	0.061	0.064	-0.092	-0.143	0.117
	p-value	0.675	0.658	0.527	0.323	0.419

Appendix Table 89: Correlations between Hip Angular Velocity and Anthropometrical Factors

3.3.4 Right Hip Torque

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
X_component						
ADDRESS	correlation	0.382	0.172	0.291	-0.328	-0.184
	p-value	0.0062	0.232	0.0407	0.0202	0.201
EARLY BS	correlation	-0.048	-0.047	0.405	-0.170	-0.767

	p-value	0.741	0.743	0.00357	0.237	<0.001
LATE BS	correlation	-0.054	0.057	0.373	0.002	-0.623
	p-value	0.71	0.694	0.0077	0.989	<0.001
INITIAL DS	correlation	-0.241	-0.012	-0.075	0.096	-0.424
	p-value	0.0917	0.933	0.607	0.509	0.00218
IMPACT	correlation	0.251	0.092	0.030	-0.096	-0.303
	p-value	0.0787	0.525	0.837	0.508	0.0322
EARLY FT	correlation	0.277	0.017	-0.004	-0.157	-0.233
	p-value	0.0518	0.908	0.98	0.276	0.104
FINISH	correlation	-0.338	-0.059	0.389	0.056	-0.127
	p-value	0.0165	0.684	0.00525	0.702	0.38
Y_component						
ADDRESS	correlation	0.134	-0.465	-0.221	-0.592	-0.284
	p-value	0.354	<0.001	0.124	<0.001	0.0454
EARLY BS	correlation	0.236	-0.164	-0.426	-0.198	0.465
	p-value	0.0991	0.254	0.00203	0.169	<0.001
LATE BS	correlation	0.135	-0.277	-0.362	-0.222	0.354
	p-value	0.35	0.0518	0.00978	0.121	0.0117
INITIAL DS	correlation	0.280	-0.188	-0.126	-0.312	0.246
	p-value	0.0491	0.191	0.385	0.0276	0.0852
IMPACT	correlation	0.389	-0.205	-0.252	-0.359	-0.409
	p-value	0.00523	0.153	0.0769	0.0104	0.00319
EARLY FT	correlation	-0.032	-0.108	-0.287	-0.193	-0.316
	p-value	0.824	0.454	0.0432	0.18	0.0254
FINISH	correlation	0.006	-0.061	-0.184	-0.203	-0.183
	p-value	0.969	0.674	0.2	0.157	0.205
Z_component						
ADDRESS	correlation	0.137	0.180	-0.082	-0.002	0.288
	p-value	0.342	0.211	0.572	0.987	0.0424
EARLY BS	correlation	-0.159	0.229	0.444	0.256	-0.309
	p-value	0.271	0.11	0.00124	0.0732	0.0291
LATE BS	correlation	-0.011	0.421	0.191	0.268	-0.135
	p-value	0.939	0.00235	0.184	0.0597	0.352
INITIAL DS	correlation	-0.054	0.450	0.049	0.241	-0.027
	p-value	0.709	0.00105	0.736	0.0921	0.853
IMPACT	correlation	-0.246	0.212	0.186	0.245	0.301
	p-value	0.0848	0.14	0.196	0.0865	0.0335
EARLY FT	correlation	-0.140	0.100	0.100	0.366	0.520
	p-value	0.334	0.491	0.491	0.00885	<0.001
FINISH	correlation	-0.219	0.104	0.225	0.266	0.263
	p-value	0.127	0.472	0.117	0.0623	0.0655

Appendix Table 90: Correlations between Right Hip Torque and Anthropometrical Factors

3.3.5 Left Hip Torque

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
X_component						
ADDRESS	correlation	-0.495	-0.009	0.175	0.333	-0.284
	p-value	<0.001	0.949	0.225	0.0182	0.046
EARLY BS	correlation	0.345	-0.311	-0.528	-0.026	0.283
	p-value	0.0142	0.0278	<0.001	0.858	0.0463
LATE BS	correlation	0.556	-0.515	-0.552	-0.182	0.209
	p-value	<0.001	<0.001	<0.001	0.206	0.146
INITIAL DS	correlation	0.260	-0.429	-0.022	-0.173	-0.309
	p-value	0.0687	0.00186	0.878	0.23	0.0292
IMPACT	correlation	-0.073	0.155	0.503	0.125	-0.317
	p-value	0.615	0.282	<0.001	0.389	0.0249
EARLY FT	correlation	0.050	0.400	0.387	0.152	-0.057
	p-value	0.732	0.00403	0.00544	0.292	0.693
FINISH	correlation	-0.374	-0.276	0.421	0.145	-0.153
	p-value	0.00744	0.052	0.00234	0.314	0.287
Y_component						
ADDRESS	correlation	-0.091	-0.282	-0.195	-0.033	0.385
	p-value	0.532	0.0474	0.175	0.821	0.00578
EARLY BS	correlation	-0.064	-0.317	-0.195	0.295	0.058
	p-value	0.66	0.0251	0.175	0.0377	0.691
LATE BS	correlation	0.390	-0.087	-0.668	0.114	0.458
	p-value	0.00512	0.55	<0.001	0.431	<0.001
INITIAL DS	correlation	0.290	0.378	-0.632	0.181	0.523
	p-value	0.0409	0.00674	<0.001	0.209	<0.001
IMPACT	correlation	0.255	0.268	-0.756	-0.184	0.510
	p-value	0.074	0.0603	<0.001	0.201	<0.001
EARLY FT	correlation	0.221	-0.300	-0.437	-0.258	0.251
	p-value	0.123	0.0342	0.00151	0.07	0.0789
FINISH	correlation	0.188	0.438	-0.126	0.092	0.223
	p-value	0.191	0.00147	0.383	0.525	0.119
Z_component						
ADDRESS	correlation	-0.155	0.185	0.360	0.314	-0.475
	p-value	0.281	0.199	0.0102	0.0262	<0.001
EARLY BS	correlation	0.214	-0.148	-0.099	0.163	-0.084
	p-value	0.135	0.305	0.494	0.257	0.562
LATE BS	correlation	0.172	-0.402	-0.034	-0.229	-0.265
	p-value	0.234	0.00384	0.815	0.11	0.0633
INITIAL DS	correlation	-0.312	-0.418	0.313	-0.242	-0.390
	p-value	0.0276	0.0025	0.0269	0.0908	0.00516
IMPACT	correlation	-0.203	-0.520	0.498	0.043	-0.511

	p-value	0.158	<0.001	<0.001	0.767	<0.001
EARLY FT	correlation	-0.228	0.284	0.441	0.263	-0.332
	p-value	0.111	0.0457	0.00133	0.0648	0.0186
FINISH	correlation	-0.228	-0.535	0.100	-0.056	-0.294
	p-value	0.112	<0.001	0.489	0.701	0.0379

Appendix Table 91: Correlations between Left Hip Torque and Anthropometrical Factors

3.4 Pelvis

3.4.1 Pelvis Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	-0.199	-0.009	-0.155	0.062	-0.146
	p-value	0.166	0.948	0.281	0.667	0.312
EARLY BS	correlation	-0.101	-0.093	-0.009	-0.167	-0.365
	p-value	0.486	0.519	0.953	0.245	0.00906
LATE BS	correlation	0.043	-0.146	-0.042	-0.278	-0.405
	p-value	0.768	0.312	0.774	0.0504	0.00355
INITIAL DS	correlation	0.206	-0.121	-0.073	-0.158	-0.172
	p-value	0.15	0.402	0.616	0.274	0.232
IMPACT	correlation	0.141	0.471	-0.154	0.438	0.492
	p-value	0.33	<0.001	0.285	0.00145	<0.001
EARLY FT	correlation	0.057	0.329	-0.083	0.397	0.406
	p-value	0.696	0.0198	0.566	0.00432	0.00343
FINISH	correlation	0.201	0.493	-0.173	0.214	0.362
	p-value	0.161	<0.001	0.228	0.136	0.00985
LATERAL FLEXION						
ADDRESS	correlation	-0.238	0.191	-0.167	0.567	0.217
	p-value	0.0956	0.184	0.246	<0.001	0.13
EARLY BS	correlation	0.418	0.138	-0.086	-0.272	-0.001
	p-value	0.00252	0.339	0.554	0.0562	0.997
LATE BS	correlation	0.351	0.134	0.017	-0.266	-0.005
	p-value	0.0124	0.355	0.906	0.0618	0.974
INITIAL DS	correlation	0.439	0.306	-0.048	-0.169	0.184
	p-value	0.00141	0.0306	0.738	0.242	0.2
IMPACT	correlation	-0.515	-0.264	0.321	0.381	-0.318
	p-value	<0.001	0.0637	0.0232	0.00628	0.0246
EARLY FT	correlation	-0.441	-0.113	0.208	0.400	-0.221
	p-value	0.00134	0.435	0.148	0.00399	0.122
FINISH	correlation	-0.183	-0.239	-0.057	-0.046	-0.361

	p-value	0.203	0.0941	0.694	0.749	0.0101
RIGHT - LEFT ROTATION						
ADDRESS	correlation	0.036	0.049	0.440	0.070	-0.191
	p-value	0.804	0.738	0.00137	0.63	0.185
EARLY BS	correlation	-0.161	-0.082	0.361	0.126	0.037
	p-value	0.265	0.573	0.0101	0.382	0.797
LATE BS	correlation	-0.118	-0.141	0.412	-0.146	-0.292
	p-value	0.415	0.33	0.00294	0.313	0.0395
INITIAL DS	correlation	0.299	-0.077	0.153	-0.519	-0.301
	p-value	0.0349	0.596	0.288	<0.001	0.0338
IMPACT	correlation	0.129	-0.294	-0.417	-0.281	0.092
	p-value	0.373	0.0382	0.00258	0.0481	0.523
EARLY FT	correlation	0.021	0.131	-0.349	0.110	0.176
	p-value	0.887	0.364	0.0129	0.446	0.221
FINISH	correlation	-0.029	0.580	0.135	0.152	0.082
	p-value	0.843	<0.001	0.35	0.291	0.57

Appendix Table 92: Correlations between Pelvis Angle and Anthropometrical Factors

3.4.2 Pelvis Angular Velocity

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
ADDRESS	correlation	0.465	0.232	-0.134	0.010	0.357
	p-value	<0.001	0.104	0.355	0.946	0.0109
EARLY BS	correlation	0.008	0.234	0.047	0.577	0.182
	p-value	0.955	0.102	0.745	<0.001	0.206
LATE BS	correlation	-0.631	0.059	0.650	0.666	-0.067
	p-value	<0.001	0.685	<0.001	<0.001	0.643
INITIAL DS	correlation	-0.455	-0.521	0.181	-0.299	-0.554
	p-value	<0.001	<0.001	0.208	0.0351	<0.001
IMPACT	correlation	0.031	-0.324	0.175	-0.281	-0.225
	p-value	0.833	0.0216	0.224	0.0481	0.116
EARLY FT	correlation	0.353	-0.374	-0.402	-0.407	0.170
	p-value	0.012	0.00752	0.00383	0.00331	0.238
FINISH	correlation	0.093	0.078	0.039	-0.125	0.166
	p-value	0.522	0.592	0.789	0.387	0.248

Appendix Table 93: Correlations between Pelvis Angular Velocity and Anthropometrical Factors

3.5 Trunk

3.5.1 Trunk Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	-0.504	-0.058	0.310	0.434	-0.068
	p-value	<0.001	0.691	0.0282	0.00163	0.639
EARLY BS	correlation	-0.563	-0.026	0.439	0.521	-0.010
	p-value	<0.001	0.858	0.00145	<0.001	0.947
LATE BS	correlation	-0.491	-0.023	0.449	0.532	0.025
	p-value	<0.001	0.876	0.00109	<0.001	0.862
INITIAL DS	correlation	-0.624	-0.035	0.652	0.587	-0.083
	p-value	<0.001	0.807	<0.001	<0.001	0.565
IMPACT	correlation	-0.386	-0.026	0.384	0.317	0.290
	p-value	0.00566	0.859	0.00596	0.0251	0.0408
EARLY FT	correlation	-0.248	-0.142	0.322	0.213	0.155
	p-value	0.0827	0.324	0.0225	0.138	0.283
FINISH	correlation	0.275	0.136	0.002	-0.007	0.220
	p-value	0.0532	0.345	0.99	0.961	0.124
LATERAL INCLINATION						
ADDRESS	correlation	0.391	-0.356	-0.294	-0.359	0.227
	p-value	0.00504	0.0111	0.0385	0.0104	0.113
EARLY BS	correlation	0.339	-0.277	-0.082	-0.212	0.002
	p-value	0.0161	0.0512	0.57	0.139	0.991
LATE BS	correlation	0.228	-0.212	0.008	-0.048	0.113
	p-value	0.111	0.139	0.959	0.739	0.436
INITIAL DS	correlation	-0.118	-0.223	0.126	-0.111	-0.122
	p-value	0.415	0.12	0.384	0.441	0.398
IMPACT	correlation	0.168	0.345	-0.042	0.422	0.369
	p-value	0.243	0.014	0.773	0.0023	0.00831
EARLY FT	correlation	0.080	0.331	-0.320	0.164	0.328
	p-value	0.581	0.0189	0.0234	0.256	0.0199
FINISH	correlation	0.423	0.114	-0.467	-0.197	0.306
	p-value	0.00221	0.43	<0.001	0.17	0.0308
RIGHT - LEFT ROTATION						
ADDRESS	correlation	0.255	0.286	-0.285	0.041	0.092
	p-value	0.0734	0.0443	0.0452	0.776	0.524
EARLY BS	correlation	0.445	-0.101	-0.084	-0.437	-0.442
	p-value	0.0012	0.485	0.56	0.00152	0.00132
LATE BS	correlation	0.526	-0.028	-0.077	-0.215	-0.115

	p-value	<0.001	0.849	0.597	0.134	0.425
INITIAL DS	correlation	0.531	0.267	-0.264	-0.117	0.117
	p-value	<0.001	0.0604	0.0636	0.419	0.417
IMPACT	correlation	0.634	-0.297	-0.504	-0.669	-0.099
	p-value	<0.001	0.0362	<0.001	<0.001	0.495
EARLY FT	correlation	0.182	0.418	-0.352	-0.229	0.116
	p-value	0.206	0.00251	0.0123	0.109	0.424
FINISH	correlation	-0.133	0.129	-0.206	0.316	0.190
	p-value	0.356	0.372	0.151	0.0254	0.186

Appendix Table 94: Correlations between Trunk Angle and Anthropometrical Factors

3.5.2 Trunk Angular Velocity

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
ADDRESS	correlation	0.250	-0.067	0.289	-0.195	-0.265
	p-value	0.0805	0.646	0.0414	0.175	0.0628
EARLY BS	correlation	0.095	-0.112	0.345	-0.001	-0.241
	p-value	0.513	0.438	0.014	0.995	0.0918
LATE BS	correlation	0.065	0.166	0.376	0.174	-0.006
	p-value	0.652	0.249	0.0071	0.226	0.966
INITIAL DS	correlation	0.377	0.338	-0.463	0.207	0.644
	p-value	0.00689	0.0163	<0.001	0.149	<0.001
IMPACT	correlation	-0.474	-0.005	0.116	0.401	0.047
	p-value	<0.001	0.975	0.423	0.00392	0.745
EARLY FT	correlation	-0.639	0.655	0.431	0.700	0.205
	p-value	<0.001	<0.001	0.00179	<0.001	0.152
FINISH	correlation	0.340	0.054	-0.272	-0.394	0.036
	p-value	0.0157	0.708	0.056	0.00467	0.802

Appendix Table 95: Correlations between Trunk Angular Velocity and Anthropometrical Factors

3.6 Head

3.6.1 Head Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	-0.481	-0.541	0.475	-0.239	-0.694
	p-value	<0.001	<0.001	<0.001	0.0939	<0.001
EARLY BS	correlation	-0.423	-0.671	0.443	-0.319	-0.636
	p-value	0.00222	<0.001	0.00127	0.0241	<0.001

LATE BS	correlation	-0.292	-0.686	0.374	-0.443	-0.629
	p-value	0.0398	<0.001	0.00741	0.00126	<0.001
INITIAL DS	correlation	-0.050	-0.554	0.145	-0.632	-0.540
	p-value	0.729	<0.001	0.314	<0.001	<0.001
IMPACT	correlation	-0.175	-0.555	0.149	-0.530	-0.437
	p-value	0.225	<0.001	0.301	<0.001	0.00153
EARLY FT	correlation	-0.168	-0.549	0.232	-0.458	-0.501
	p-value	0.245	<0.001	0.105	<0.001	<0.001
FINISH	correlation	-0.112	-0.763	0.251	-0.293	-0.416
	p-value	0.438	<0.001	0.0783	0.039	0.00263
LATERAL FLEXION						
ADDRESS	correlation	0.140	0.167	-0.599	-0.146	0.283
	p-value	0.331	0.245	<0.001	0.311	0.0465
EARLY BS	correlation	0.516	0.198	-0.423	-0.039	0.477
	p-value	<0.001	0.168	0.00223	0.79	<0.001
LATE BS	correlation	0.365	0.349	-0.166	0.164	0.410
	p-value	0.00917	0.0131	0.249	0.256	0.00307
INITIAL DS	correlation	0.282	0.745	0.005	0.521	0.579
	p-value	0.0469	<0.001	0.974	<0.001	<0.001
IMPACT	correlation	0.476	-0.240	-0.694	-0.557	-0.085
	p-value	<0.001	0.0926	<0.001	<0.001	0.558
EARLY FT	correlation	0.254	-0.385	-0.542	-0.740	-0.327
	p-value	0.0746	0.00571	<0.001	<0.001	0.0205
FINISH	correlation	-0.309	-0.589	0.034	-0.575	-0.690
	p-value	0.0292	<0.001	0.816	<0.001	<0.001
RIGHT - LEFT ROTATION						
ADDRESS	correlation	-0.006	0.172	0.486	0.310	0.188
	p-value	0.966	0.232	<0.001	0.0286	0.191
EARLY BS	correlation	-0.251	0.097	0.396	0.481	0.295
	p-value	0.0787	0.504	0.00444	<0.001	0.0376
LATE BS	correlation	-0.316	-0.021	0.453	0.139	-0.121
	p-value	0.0252	0.885	<0.001	0.335	0.401
INITIAL DS	correlation	-0.263	0.175	0.337	0.026	-0.068
	p-value	0.0653	0.225	0.0168	0.858	0.639
IMPACT	correlation	-0.063	0.375	-0.433	0.239	0.485
	p-value	0.662	0.00735	0.00168	0.095	<0.001
EARLY FT	correlation	-0.031	0.263	-0.488	0.181	0.290
	p-value	0.831	0.0652	<0.001	0.209	0.0414
FINISH	correlation	-0.413	0.358	-0.067	0.159	-0.040
	p-value	0.00289	0.0106	0.642	0.27	0.783

Appendix Table 96: Correlations between Head Angle and Anthropometrical Factors

3.6.2 Head Angular Velocity

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
ADDRESS	correlation	0.279	0.154	-0.669	-0.269	0.249
	p-value	0.05	0.284	<0.001	0.0584	0.0818
EARLY BS	correlation	0.028	-0.006	-0.446	-0.284	0.171
	p-value	0.845	0.965	0.00118	0.046	0.234
LATE BS	correlation	0.144	-0.090	-0.545	-0.441	0.047
	p-value	0.318	0.533	<0.001	0.00135	0.746
INITIAL DS	correlation	-0.208	-0.391	0.002	-0.621	-0.596
	p-value	0.147	0.00493	0.99	<0.001	<0.001
IMPACT	correlation	-0.132	-0.259	-0.044	-0.060	0.045
	p-value	0.362	0.0696	0.763	0.681	0.755
EARLY FT	correlation	-0.342	0.549	0.221	0.589	0.379
	p-value	0.0149	<0.001	0.124	<0.001	0.00671
FINISH	correlation	0.098	-0.063	0.052	-0.294	0.068
	p-value	0.499	0.665	0.718	0.0386	0.637

Appendix Table 97: Correlations between Head Angular Velocity and Anthropometrical Factors

3.7 Shoulder

3.7.1 Right Shoulder Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	-0.616	0.265	0.494	0.897	0.201
	p-value	<0.001	0.0632	<0.001	<0.001	0.162
EARLY BS	correlation	-0.200	0.324	0.030	0.426	0.416
	p-value	0.165	0.0218	0.837	0.00202	0.00265
LATE BS	correlation	-0.382	-0.238	0.307	0.252	0.037
	p-value	0.00618	0.0967	0.0299	0.0771	0.797
INITIAL DS	correlation	0.638	0.197	-0.777	-0.198	0.422
	p-value	<0.001	0.17	<0.001	0.168	0.00225
IMPACT	correlation	-0.287	0.286	0.463	0.686	0.127
	p-value	0.043	0.0439	<0.001	<0.001	0.378
EARLY FT	correlation	-0.238	0.481	0.196	0.766	0.432
	p-value	0.0965	<0.001	0.174	<0.001	0.00173
FINISH	correlation	-0.116	-0.220	-0.060	-0.119	-0.077
	p-value	0.423	0.126	0.681	0.409	0.593

PRONATION-SUPINATION						
ADDRESS	correlation	-0.759	-0.086	0.311	0.149	-0.053
	p-value	<0.001	0.553	0.0281	0.301	0.713
EARLY BS	correlation	-0.786	0.114	0.541	0.233	-0.092
	p-value	<0.001	0.431	<0.001	0.103	0.525
LATE BS	correlation	-0.604	0.364	0.373	0.137	0.021
	p-value	<0.001	0.00944	0.0077	0.342	0.885
INITIAL DS	correlation	-0.705	0.382	0.509	0.488	0.054
	p-value	<0.001	0.00619	<0.001	<0.001	0.712
IMPACT	correlation	-0.547	0.227	0.162	0.178	0.244
	p-value	<0.001	0.113	0.262	0.216	0.0871
EARLY FT	correlation	-0.509	-0.049	0.223	-0.105	-0.127
	p-value	<0.001	0.737	0.119	0.466	0.381
FINISH	correlation	-0.587	-0.315	0.184	-0.305	-0.504
	p-value	<0.001	0.0259	0.201	0.0314	<0.001

Appendix Table 98: Correlations between Right Shoulder Angle and Anthropometrical Factors

3.7.2 Left Shoulder Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	-0.389	0.339	0.512	0.876	0.281
	p-value	0.0052	0.0159	<0.001	<0.001	0.0483
EARLY BS	correlation	-0.092	0.229	0.082	0.685	0.582
	p-value	0.524	0.11	0.571	<0.001	<0.001
LATE BS	correlation	0.130	0.118	-0.149	0.386	0.438
	p-value	0.37	0.413	0.301	0.00567	0.00146
INITIAL DS	correlation	0.574	0.143	-0.694	-0.120	0.357
	p-value	<0.001	0.321	<0.001	0.406	0.0109
IMPACT	correlation	0.382	-0.127	-0.432	-0.563	-0.226
	p-value	0.00613	0.379	0.00172	<0.001	0.114
EARLY FT	correlation	0.162	0.385	-0.314	-0.204	0.011
	p-value	0.262	0.00581	0.0265	0.155	0.938
FINISH	correlation	-0.445	-0.073	0.481	0.324	0.055
	p-value	0.0012	0.613	<0.001	0.0219	0.704
PRONATION-SUPINATION						
ADDRESS	correlation	0.181	-0.097	0.113	0.057	0.179
	p-value	0.208	0.503	0.433	0.696	0.214
EARLY BS	correlation	-0.056	0.012	0.306	0.119	0.026
	p-value	0.699	0.932	0.0304	0.412	0.859
LATE BS	correlation	0.086	-0.021	0.116	-0.078	0.037

	p-value	0.552	0.883	0.422	0.592	0.799
INITIAL DS	correlation	-0.079	0.084	0.086	0.282	0.320
	p-value	0.587	0.561	0.553	0.0469	0.0237
IMPACT	correlation	-0.077	-0.053	0.159	-0.039	0.044
	p-value	0.595	0.714	0.27	0.786	0.76
EARLY FT	correlation	0.443	0.057	-0.034	-0.112	0.082
	p-value	0.00126	0.696	0.816	0.438	0.569
FINISH	correlation	0.029	-0.144	-0.388	-0.240	-0.320
	p-value	0.84	0.317	0.00542	0.0928	0.0237

Appendix Table 99: Correlations between Left Shoulder Angle and Anthropometrical Factors

3.7.3 Shoulder Angular Velocity

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
RIGHT						
ADDRESS	correlation	-0.511	-0.263	0.082	-0.145	-0.363
	p-value	<0.001	0.0655	0.57	0.315	0.00966
EARLY BS	correlation	0.306	0.546	-0.183	-0.129	0.185
	p-value	0.0306	<0.001	0.202	0.37	0.199
LATE BS	correlation	0.179	0.391	-0.245	0.150	0.200
	p-value	0.213	0.00499	0.0859	0.298	0.163
INITIAL DS	correlation	-0.311	-0.286	0.558	-0.028	-0.428
	p-value	0.0278	0.0443	<0.001	0.845	0.00194
IMPACT	correlation	0.174	-0.291	0.022	0.264	0.218
	p-value	0.228	0.0404	0.879	0.0637	0.129
EARLY FT	correlation	0.597	-0.149	-0.099	0.013	0.079
	p-value	<0.001	0.301	0.492	0.926	0.584
FINISH	correlation	0.256	0.032	-0.101	-0.168	0.335
	p-value	0.0727	0.826	0.485	0.242	0.0173
LEFT						
ADDRESS	correlation	-0.076	-0.174	-0.418	-0.487	-0.051
	p-value	0.6	0.226	0.00253	<0.001	0.726
EARLY BS	correlation	0.071	-0.033	-0.305	-0.563	-0.163
	p-value	0.622	0.822	0.0313	<0.001	0.258
LATE BS	correlation	0.186	0.112	-0.447	-0.477	0.006
	p-value	0.196	0.44	0.00113	<0.001	0.967
INITIAL DS	correlation	0.363	-0.032	-0.349	0.080	0.290
	p-value	0.00963	0.827	0.0131	0.579	0.041
IMPACT	correlation	0.080	0.524	0.078	0.546	0.597
	p-value	0.581	<0.001	0.589	<0.001	<0.001
EARLY FT	correlation	0.430	0.110	-0.085	0.024	-0.128

	p-value	0.00183	0.446	0.556	0.867	0.376
FINISH	correlation	-0.060	-0.207	0.175	-0.388	-0.134
	p-value	0.678	0.149	0.224	0.00538	0.354

Appendix Table 100: Correlations between Shoulder Angular Velocity and Anthropometrical Factors

3.8 Elbow

3.8.1 Right Elbow Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	0.413	0.342	-0.123	0.130	0.295
	p-value	0.00285	0.0151	0.395	0.369	0.0379
EARLY BS	correlation	0.502	0.339	-0.427	0.104	0.427
	p-value	<0.001	0.0161	0.002	0.471	0.00198
LATE BS	correlation	0.352	0.286	-0.217	0.135	0.133
	p-value	0.0121	0.0439	0.13	0.351	0.358
INITIAL DS	correlation	0.056	0.091	0.137	0.368	-0.000
	p-value	0.701	0.528	0.341	0.00849	1
IMPACT	correlation	0.181	0.166	-0.057	0.258	0.114
	p-value	0.207	0.248	0.694	0.0705	0.429
EARLY FT	correlation	-0.506	-0.147	0.379	0.179	-0.393
	p-value	<0.001	0.309	0.00661	0.213	0.00479
FINISH	correlation	0.064	0.050	-0.087	0.309	-0.011
	p-value	0.661	0.731	0.546	0.0292	0.941
EXTERNAL – INTERNAL ROTATION						
ADDRESS	correlation	0.294	0.142	-0.005	0.313	0.006
	p-value	0.038	0.327	0.97	0.0269	0.966
EARLY BS	correlation	0.507	0.240	-0.264	0.170	0.302
	p-value	<0.001	0.0926	0.0641	0.237	0.0332
LATE BS	correlation	0.336	0.071	-0.136	0.153	0.116
	p-value	0.0171	0.624	0.345	0.288	0.422
INITIAL DS	correlation	0.083	-0.259	0.101	0.010	-0.300
	p-value	0.566	0.0693	0.484	0.944	0.0343
IMPACT	correlation	0.440	0.197	0.000	-0.177	-0.171
	p-value	0.0014	0.169	0.999	0.218	0.234
EARLY FT	correlation	-0.229	-0.151	0.414	0.145	-0.336
	p-value	0.109	0.297	0.00283	0.315	0.0172
FINISH	correlation	0.058	-0.401	0.039	-0.022	-0.112
	p-value	0.692	0.00386	0.787	0.882	0.44

Appendix Table 101: Correlations between Right Elbow Angle and Anthropometrical Factors

3.8.2 Left Elbow Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	0.027	0.418	0.168	-0.008	0.295
	p-value	0.85	0.00256	0.243	0.954	0.0379
EARLY BS	correlation	0.087	0.396	0.003	-0.116	0.323
	p-value	0.546	0.00446	0.981	0.422	0.0222
LATE BS	correlation	0.419	0.223	-0.137	-0.106	0.057
	p-value	0.00245	0.119	0.344	0.464	0.694
INITIAL DS	correlation	0.369	0.058	-0.319	-0.083	0.047
	p-value	0.00845	0.691	0.0237	0.565	0.748
IMPACT	correlation	-0.010	-0.557	-0.323	-0.600	-0.343
	p-value	0.945	<0.001	0.0222	<0.001	0.0148
EARLY FT	correlation	-0.006	-0.257	-0.423	-0.500	-0.042
	p-value	0.968	0.072	0.00221	<0.001	0.77
FINISH	correlation	0.094	0.132	-0.172	0.271	-0.043
	p-value	0.516	0.361	0.232	0.0565	0.765
EXTERNAL – INTERNAL ROTATION						
ADDRESS	correlation	0.310	-0.205	0.182	-0.264	-0.107
	p-value	0.0283	0.153	0.207	0.0639	0.459
EARLY BS	correlation	0.105	-0.196	0.389	-0.230	-0.223
	p-value	0.469	0.172	0.0053	0.108	0.119
LATE BS	correlation	0.512	0.044	0.089	-0.149	0.147
	p-value	<0.001	0.76	0.538	0.301	0.308
INITIAL DS	correlation	0.847	0.176	-0.622	-0.434	0.222
	p-value	<0.001	0.223	<0.001	0.00166	0.122
IMPACT	correlation	0.327	-0.396	-0.288	-0.459	-0.049
	p-value	0.0207	0.00444	0.0426	<0.001	0.737
EARLY FT	correlation	0.371	-0.173	-0.087	-0.461	-0.090
	p-value	0.00801	0.229	0.546	<0.001	0.535
FINISH	correlation	0.684	-0.285	-0.395	-0.479	-0.010
	p-value	<0.001	0.045	0.0045	<0.001	0.946

Appendix Table 102: Correlations between Left Elbow Angle and Anthropometrical Factors

3.8.3 Elbow Angular Velocity

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
RIGHT						
ADDRESS	correlation	0.355	0.022	-0.676	-0.282	0.190
	p-value	0.0113	0.88	<0.001	0.0476	0.187
EARLY BS	correlation	0.317	0.128	-0.248	0.130	0.256
	p-value	0.0249	0.374	0.0824	0.37	0.0723
LATE BS	correlation	0.053	0.149	-0.460	0.201	0.327
	p-value	0.717	0.303	<0.001	0.162	0.0206
INITIAL DS	correlation	0.065	0.307	-0.461	-0.033	0.085
	p-value	0.652	0.03	<0.001	0.821	0.559
IMPACT	correlation	0.203	0.499	-0.034	0.511	0.256
	p-value	0.156	<0.001	0.815	<0.001	0.0731
EARLY FT	correlation	0.506	-0.036	-0.189	-0.529	-0.416
	p-value	<0.001	0.804	0.189	<0.001	0.00265
FINISH	correlation	0.113	-0.235	0.011	-0.381	-0.150
	p-value	0.435	0.101	0.937	0.00627	0.298
LEFT						
ADDRESS	correlation	0.278	-0.123	-0.637	-0.265	0.044
	p-value	0.0509	0.393	<0.001	0.0631	0.76
EARLY BS	correlation	0.040	0.145	-0.426	-0.032	0.375
	p-value	0.784	0.316	0.00205	0.825	0.00728
LATE BS	correlation	0.284	-0.262	-0.318	-0.517	-0.273
	p-value	0.0453	0.0661	0.0243	<0.001	0.055
INITIAL DS	correlation	0.071	0.156	0.039	-0.049	0.210
	p-value	0.624	0.28	0.79	0.733	0.144
IMPACT	correlation	-0.024	0.132	0.489	0.078	-0.017
	p-value	0.867	0.361	<0.001	0.59	0.905
EARLY FT	correlation	-0.212	0.129	0.667	0.460	-0.191
	p-value	0.139	0.374	<0.001	<0.001	0.185
FINISH	correlation	0.093	-0.039	0.150	-0.051	-0.022
	p-value	0.527	0.79	0.304	0.73	0.879

Appendix Table 103: Correlations between Elbow Angular Velocity and Anthropometrical Factors

3.9 Hand

3.9.1 Right Hand Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	0.192	-0.097	0.237	-0.267	-0.057
	p-value	0.181	0.503	0.0978	0.0612	0.696
EARLY BS	correlation	-0.172	-0.260	0.064	0.054	0.276
	p-value	0.233	0.0681	0.66	0.708	0.0524
LATE BS	correlation	0.400	0.016	-0.212	-0.241	0.500
	p-value	0.00402	0.914	0.139	0.0916	<0.001
INITIAL DS	correlation	0.686	0.210	-0.390	-0.192	0.556
	p-value	<0.001	0.143	0.00509	0.182	<0.001
IMPACT	correlation	0.467	-0.269	-0.440	-0.111	0.327
	p-value	<0.001	0.0618	0.00154	0.448	0.0216
EARLY FT	correlation	0.101	-0.395	-0.282	-0.372	0.155
	p-value	0.486	0.00455	0.0472	0.00776	0.281
FINISH	correlation	0.184	-0.253	0.268	-0.150	-0.220
	p-value	0.221	0.0898	0.0715	0.319	0.141
ULNAR-RADIAL DEVIATION						
ADDRESS	correlation	-0.254	-0.423	0.404	-0.340	-0.703
	p-value	0.0745	0.00223	0.00362	0.0157	<0.001
EARLY BS	correlation	-0.220	-0.512	0.079	-0.174	-0.387
	p-value	0.124	<0.001	0.586	0.227	0.0055
LATE BS	correlation	0.175	-0.144	-0.048	-0.271	0.282
	p-value	0.223	0.318	0.741	0.057	0.0475
INITIAL DS	correlation	-0.456	-0.335	0.635	-0.026	-0.407
	p-value	<0.001	0.0174	<0.001	0.858	0.00338
IMPACT	correlation	-0.238	-0.234	0.410	-0.282	-0.451
	p-value	0.096	0.102	0.00311	0.0477	0.00103
EARLY FT	correlation	0.075	-0.641	-0.104	-0.391	-0.273
	p-value	0.603	<0.001	0.471	0.005	0.0548
FINISH	correlation	-0.421	-0.239	0.745	0.161	-0.412
	p-value	0.00287	0.101	<0.001	0.275	0.00362

Appendix Table 104: Correlations between Right Hand Angle and Anthropometrical Factors

3.9.2 Left Hand Angle

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
FLEXION -EXTENSION						
ADDRESS	correlation	-0.332	0.123	0.171	0.406	0.069
	p-value	0.0185	0.396	0.236	0.00344	0.633
EARLY BS	correlation	-0.261	0.442	0.250	0.446	0.268
	p-value	0.0675	0.0013	0.0805	0.00117	0.0597
LATE BS	correlation	-0.466	0.268	0.326	0.466	-0.244
	p-value	<0.001	0.0598	0.0207	<0.001	0.0872
INITIAL DS	correlation	-0.439	0.428	0.316	0.297	0.089
	p-value	0.00143	0.00191	0.0256	0.0362	0.54
IMPACT	correlation	-0.417	0.652	0.511	0.582	0.230
	p-value	0.00257	<0.001	<0.001	<0.001	0.108
EARLY FT	correlation	-0.410	0.457	0.596	0.670	0.200
	p-value	0.00313	<0.001	<0.001	<0.001	0.163
FINISH	correlation	0.042	0.511	-0.255	0.535	0.812
	p-value	0.775	<0.001	0.0807	<0.001	<0.001
ULNAR-RADIAL DEVIATION						
ADDRESS	correlation	-0.355	-0.236	0.215	0.054	-0.555
	p-value	0.0113	0.0989	0.133	0.708	<0.001
EARLY BS	correlation	-0.087	0.058	0.149	-0.039	-0.561
	p-value	0.549	0.69	0.302	0.787	<0.001
LATE BS	correlation	-0.413	0.095	0.308	0.321	-0.455
	p-value	0.00288	0.513	0.0295	0.0231	<0.001
INITIAL DS	correlation	-0.437	0.368	0.298	0.213	-0.298
	p-value	0.00151	0.0086	0.0358	0.137	0.0357
IMPACT	correlation	-0.122	0.382	0.317	0.264	-0.273
	p-value	0.399	0.00612	0.0251	0.0641	0.0555
EARLY FT	correlation	-0.181	0.431	0.307	0.105	-0.095
	p-value	0.209	0.0018	0.0303	0.466	0.511
FINISH	correlation	-0.614	0.315	0.476	0.226	-0.193
	p-value	<0.001	0.0291	<0.001	0.122	0.189

Appendix Table 105: Correlations between Left Hand Angle and Anthropometrical Factors

3.9.3 Hand Angular Velocity

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
RIGHT						
ADDRESS	correlation	0.239	0.077	-0.612	-0.200	0.175
	p-value	0.0952	0.595	<0.001	0.164	0.223
EARLY BS	correlation	-0.061	0.084	-0.219	-0.213	0.306
	p-value	0.709	0.607	0.174	0.188	0.055
LATE BS	correlation	-0.460	-0.402	0.225	0.346	0.076
	p-value	0.00367	0.0124	0.175	0.0334	0.651
INITIAL DS	correlation	-0.325	-0.227	0.037	-0.313	-0.380
	p-value	0.0214	0.113	0.798	0.0267	0.00652
IMPACT	correlation	-0.588	-0.155	0.638	0.312	-0.288
	p-value	<0.001	0.282	<0.001	0.0277	0.0428
EARLY FT	correlation	-0.010	0.121	-0.305	0.376	0.291
	p-value	0.947	0.403	0.031	0.00705	0.0406
FINISH	correlation	0.176	-0.117	-0.092	-0.329	0.080
	p-value	0.233	0.429	0.534	0.0226	0.59
LEFT						
ADDRESS	correlation	0.112	-0.118	-0.495	-0.058	0.034
	p-value	0.438	0.414	<0.001	0.689	0.813
EARLY BS	correlation	-0.202	-0.072	-0.096	0.099	0.263
	p-value	0.204	0.655	0.55	0.538	0.0973
LATE BS	correlation	-0.251	-0.388	0.049	0.201	0.155
	p-value	0.119	0.0134	0.766	0.214	0.34
INITIAL DS	correlation	-0.083	0.059	-0.045	-0.199	0.147
	p-value	0.565	0.686	0.756	0.166	0.31
IMPACT	correlation	-0.698	0.329	0.462	0.788	0.117
	p-value	<0.001	0.0195	<0.001	<0.001	0.417
EARLY FT	correlation	0.020	-0.036	-0.078	0.259	-0.135
	p-value	0.891	0.804	0.592	0.069	0.351
FINISH	correlation	-0.161	-0.032	0.210	0.129	-0.021
	p-value	0.281	0.831	0.156	0.387	0.891

Appendix Table 106: : Correlations between Hand Angular Velocity and Anthropometrical Factors

3.10 X Factor

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
X_FACTOR_top	correlation	-0.203	-0.566	-0.025	-0.418	-0.327
	p-value*	0.157	<0.001	0.862	0.00249	0.0205
X_FACTOR_stretch_rel	correlation	0.030	0.405	0.479	0.319	0.233
	p-value*	0.836	0.00353	<0.001	0.0241	0.103
X_FACTOR_mid_impact	correlation	-0.445	0.076	0.338	0.328	-0.045
	p-value*	0.0012	0.602	0.0163	0.0201	0.755

Appendix Table 107: Correlations between X factor and Anthropometrical Factors

3.11 Time

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
t_swing_s	correlation	0.205	-0.274	-0.159	0.016	0.042
	p-value*	0.154	0.0541	0.269	0.913	0.774
t_backswing_s	correlation	0.122	0.144	0.324	0.127	-0.076
	p-value*	0.398	0.317	0.0218	0.381	0.598
t_downswing_s	correlation	0.484	0.492	-0.073	0.001	0.387
	p-value*	<0.001	<0.001	0.612	0.994	0.00556

Appendix Table 108: Correlations between Time and Anthropometrical Factors

3.12 GRF

3.12 .1 Right GRF

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
X_component						
ADDRESS	correlation	-0.162	0.096	-0.334	0.025	0.187
	p-value	0.262	0.507	0.0177	0.862	0.193
EARLY BS	correlation	0.254	0.009	-0.026	-0.429	0.067
	p-value	0.0753	0.951	0.859	0.00191	0.646
LATE BS	correlation	0.219	0.056	-0.038	-0.179	0.225
	p-value	0.126	0.698	0.794	0.213	0.116
INITIAL DS	correlation	0.018	0.544	0.257	0.431	0.529
	p-value	0.901	<0.001	0.0715	0.00177	<0.001
IMPACT	correlation	-0.142	0.279	-0.091	0.198	0.268
	p-value	0.327	0.0501	0.529	0.169	0.0595

EARLY FT	correlation	0.232	-0.346	0.079	-0.519	-0.332
	p-value	0.105	0.0137	0.584	<0.001	0.0183
FINISH	correlation	-0.153	0.050	0.398	0.089	-0.017
	p-value	0.288	0.733	0.00418	0.538	0.909
Y_component						
ADDRESS	correlation	0.107	-0.614	-0.011	-0.348	-0.352
	p-value	0.46	<0.001	0.941	0.0134	0.0121
EARLY BS	correlation	0.131	-0.276	0.076	-0.297	-0.668
	p-value	0.365	0.0525	0.602	0.0362	<0.001
LATE BS	correlation	0.122	-0.291	0.125	-0.480	-0.765
	p-value	0.399	0.0406	0.387	<0.001	<0.001
INITIAL DS	correlation	0.038	-0.071	0.047	-0.507	-0.606
	p-value	0.795	0.624	0.744	<0.001	<0.001
IMPACT	correlation	-0.063	0.079	0.298	0.290	-0.302
	p-value	0.666	0.587	0.0357	0.0411	0.0329
EARLY FT	correlation	0.107	-0.058	-0.632	-0.015	0.195
	p-value	0.46	0.69	<0.001	0.915	0.174
FINISH	correlation	0.066	0.124	-0.502	-0.332	0.074
	p-value	0.648	0.389	<0.001	0.0184	0.609
Z_component						
ADDRESS	correlation	-0.097	0.331	-0.431	0.461	0.488
	p-value	0.501	0.0188	0.0018	<0.001	<0.001
EARLY BS	correlation	0.155	0.089	-0.550	0.340	0.783
	p-value	0.283	0.54	<0.001	0.0156	<0.001
LATE BS	correlation	0.390	0.001	-0.647	0.257	0.726
	p-value	0.00507	0.992	<0.001	0.072	<0.001
INITIAL DS	correlation	0.312	0.128	-0.022	0.458	0.542
	p-value	0.0274	0.375	0.882	<0.001	<0.001
IMPACT	correlation	-0.012	0.089	-0.238	0.301	0.561
	p-value	0.933	0.539	0.0961	0.0336	<0.001
EARLY FT	correlation	0.091	0.233	0.445	0.372	0.175
	p-value	0.53	0.103	0.00122	0.00779	0.225
FINISH	correlation	0.423	0.178	-0.060	0.120	0.406
	p-value	0.00219	0.215	0.679	0.406	0.00347

Appendix Table 109: Correlations between Right GRF and Anthropometrical Factors

3.12 .2 Left GRF

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
X_component						
ADDRESS	correlation	0.108	-0.287	0.187	-0.291	-0.277
	p-value	0.455	0.0434	0.193	0.0406	0.0511
EARLY BS	correlation	-0.281	-0.262	0.506	0.350	-0.397

	p-value	0.0478	0.0664	<0.001	0.0128	0.00432
LATE BS	correlation	-0.300	-0.114	0.203	0.277	-0.232
	p-value	0.0344	0.431	0.158	0.0511	0.106
INITIAL DS	correlation	-0.209	-0.649	-0.210	-0.274	-0.495
	p-value	0.146	<0.001	0.142	0.054	<0.001
IMPACT	correlation	0.395	-0.321	-0.692	-0.330	0.422
	p-value	0.00455	0.0229	<0.001	0.0191	0.0023
EARLY FT	correlation	-0.019	-0.034	0.073	-0.059	-0.320
	p-value	0.896	0.813	0.612	0.684	0.0235
FINISH	correlation	0.069	-0.142	-0.357	-0.199	-0.054
	p-value	0.633	0.326	0.0108	0.166	0.707
Y_component						
ADDRESS	correlation	0.032	0.366	-0.070	0.576	0.541
	p-value	0.827	0.00889	0.627	<0.001	<0.001
EARLY BS	correlation	-0.117	0.306	0.336	0.096	-0.072
	p-value	0.418	0.0306	0.0169	0.509	0.619
LATE BS	correlation	-0.400	0.404	0.463	0.324	-0.004
	p-value	0.004	0.00359	<0.001	0.0218	0.977
INITIAL DS	correlation	-0.209	0.563	0.494	0.510	0.410
	p-value	0.145	<0.001	<0.001	<0.001	0.00314
IMPACT	correlation	0.309	0.650	-0.073	0.044	0.425
	p-value	0.0292	<0.001	0.613	0.761	0.00207
EARLY FT	correlation	0.489	0.102	-0.292	-0.214	0.317
	p-value	<0.001	0.482	0.0394	0.136	0.0251
FINISH	correlation	-0.219	-0.023	0.634	0.383	-0.154
	p-value	0.127	0.876	<0.001	0.00611	0.287
Z_component						
ADDRESS	correlation	0.506	0.162	-0.294	0.303	0.642
	p-value	<0.001	0.262	0.0379	0.0325	<0.001
EARLY BS	correlation	-0.079	0.312	0.423	0.214	-0.295
	p-value	0.586	0.0272	0.00221	0.136	0.0376
LATE BS	correlation	-0.475	0.661	0.603	0.522	-0.163
	p-value	<0.001	<0.001	<0.001	<0.001	0.257
INITIAL DS	correlation	-0.241	0.394	-0.153	0.438	0.348
	p-value	0.0915	0.0046	0.289	0.00145	0.0132
IMPACT	correlation	0.374	0.271	-0.812	-0.310	0.489
	p-value	0.00738	0.0569	<0.001	0.0286	<0.001
EARLY FT	correlation	0.325	-0.299	-0.375	-0.257	0.132
	p-value	0.0215	0.0351	0.00729	0.0716	0.363
FINISH	correlation	-0.194	0.182	-0.233	0.501	0.257
	p-value	0.176	0.205	0.104	<0.001	0.0714

Appendix Table 110: Correlations between Left GRF and Anthropometrical Factors

3.13 Ground Reaction Torques

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
ADDRESS	correlation	-0.223	0.267	0.357	0.130	0.026
	p-value	0.12	0.0611	0.0109	0.369	0.858
EARLY BS	correlation	0.041	0.346	-0.023	0.347	0.701
	p-value	0.775	0.0139	0.873	0.0136	<0.001
LATE BS	correlation	0.038	0.270	-0.352	0.196	0.764
	p-value	0.795	0.0584	0.0121	0.172	<0.001
INITIAL DS	correlation	0.277	0.414	-0.431	-0.087	0.658
	p-value	0.0515	0.0028	0.00177	0.548	<0.001
IMPACT	correlation	-0.247	-0.336	0.711	-0.076	-0.574
	p-value	0.0835	0.0169	<0.001	0.599	<0.001
EARLY FT	correlation	-0.377	0.093	0.184	0.119	-0.362
	p-value	0.00691	0.52	0.201	0.411	0.00985
FINISH	correlation	-0.106	-0.399	0.200	-0.391	-0.432
	p-value	0.462	0.00409	0.164	0.005	0.00173

Appendix Table 111: Correlations between GR Torques and Anthropometrical Factors

3.14 COP displacement

Position		Endomorphy	Mesomorphy	Ectomorphy	Body height	Body Mass
X_component						
ADDRESS	correlation	0.552	-0.370	-0.320	-0.821	-0.353
	p-value	<0.001	0.0082	0.0235	<0.001	0.0119
EARLY BS	correlation	0.397	-0.210	-0.459	-0.689	-0.261
	p-value	0.0043	0.143	<0.001	<0.001	0.0674
LATE BS	correlation	0.298	-0.244	-0.384	-0.707	-0.353
	p-value	0.0353	0.0871	0.00586	<0.001	0.012
INITIAL DS	correlation	0.606	0.045	-0.468	-0.684	-0.132
	p-value	<0.001	0.757	<0.001	<0.001	0.362
IMPACT	correlation	0.382	-0.213	-0.757	-0.551	0.143
	p-value	0.00619	0.137	<0.001	<0.001	0.322
EARLY FT	correlation	0.399	-0.436	-0.602	-0.565	0.080
	p-value	0.0041	0.00157	<0.001	<0.001	0.583
FINISH	correlation	0.294	-0.179	-0.749	-0.441	0.169
	p-value	0.038	0.213	<0.001	0.00133	0.241
Y_component						
ADDRESS	correlation	-0.530	0.143	-0.046	0.259	-0.055
	p-value	<0.001	0.322	0.753	0.069	0.703
EARLY BS	correlation	-0.239	-0.205	-0.299	0.188	0.354

	p-value	0.0951	0.152	0.0346	0.19	0.0115
LATE BS	correlation	0.210	-0.458	-0.574	-0.014	0.345
	p-value	0.142	<0.001	<0.001	0.921	0.014
INITIAL DS	correlation	0.174	-0.048	0.033	0.270	0.208
	p-value	0.226	0.74	0.821	0.0578	0.148
IMPACT	correlation	-0.485	-0.230	0.664	0.504	-0.281
	p-value	<0.001	0.108	<0.001	<0.001	0.048
EARLY FT	correlation	-0.376	0.183	0.414	0.264	-0.156
	p-value	0.00704	0.203	0.00279	0.064	0.278
FINISH	correlation	0.259	0.260	0.063	-0.078	0.142
	p-value	0.0695	0.068	0.666	0.592	0.325

Appendix Table 112: Correlations between COP Displacement and Anthropometrical Factors

4. Mutual correlation between performing factors

Position		Club Head Speed at Impact	Horizontal Launch Angle	Handicap
Club Head Speed at Impact	correlation		0.508	0.020
	p-value*		<0.001	0.888
Horizontal Launch Angle	correlation	0.508		-0.081
	p-value*	<0.001		0.578
Handicap	correlation	0.020	0.241	
	p-value*	0.888	0.0924	

APPENDIX IV – Glossary

AB-AD	Adduction/Abduction
BS	Back Swing
C	Ectomorphy
CHS	Club Head Speed
COP	Centre of Pressure
COP X	Medio/Lateral Displacement of COP
COP Y	Antero/Posterior Displacement of COP
DS	Downswing
E	Endomorphy
E-I	External/Internal Rotation
F-E	Flexion/Extension
FT	Follow Through
GR Torques	Ground Reacion Torques
GRF	Ground Reaction Force
H	Handicap
H	Height
HLA	Horizontal Launch Angle
ini	Initial
KKV	Kinetic and Kinematic Variables
LAT. FLEX.	Lateral Flexion
M	Mesomorphy
PRON-SUP.	Pronation/Supination
RIGHT-LEFT ROT.	Right/Left Rotation
ROM	Range of Motion
T	Articular Torque
t	Time
top	Top of Backswing
ULNAR-RADIAL DEV.	Ulnar/Radial Deviation
v	Angular Velocity
W	Body Mass

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