Ground reaction force in the kinetic analysis of the sporting gesture shot in lower limbs

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Abstract—The adapted sports emerged in the postwar period, with the aim of rehabilitating and reintegrating amputees and spinal cord injuries. Among the team sports there is the amputee soccer, which has, recently, been target of tactics and biomechanical evaluations to assess performance and direct the training of players. Thus, this study has the objective of analyzing the behavior of components of the Ground Reaction Force (GRF) associated with risk of injury to the musculoskeletal system generated by the support of both lower limbs of amputated athletes, compared with non-amputee athletes. Therefore, here, it is possible to observe that the evaluated athletes adapted to amputation differently, presenting forces with significant differences in comparison to non-amputees. Confronting the literature data and those presented by this study, it can be inferred that amputated and non-amputated athletes have a considerable difference regarding the values of mediolateral GRF, anteroposterior GRF and duration of support, when the amputee support for the soccer kick requires the use of crutches. A better understanding and monitoring of the kicking sporting gesture in amputees soccer needs more studies in order to increase the life quality and performance of the athletes.

Keywords—amputees, soccer amputee, ground reaction force, kick.

Resumen—Los deportes adaptados surgieron en la posguerra, con el objetivo de rehabilitar y reintegrar a los amputados y las lesiones de la médula espinal. Entre los deportes de equipo se encuentra el fútbol para amputados, que recientemente ha sido objeto de tácticas y evaluaciones biomecánicas para evaluar el rendimiento y dirigir el entrenamiento de los jugadores. Por lo tanto, este estudio tiene el objetivo de analizar el comportamiento de los componentes de la Fuerza de reacción terrestre (FRT) asociados con el riesgo de lesión del sistema musculoesquelético generado por el apoyo de ambos miembros inferiores de los atletas amputados, en comparación con los atletas no amputados. Por lo tanto, aquí, es posible observar que los atletas evaluados se adaptaron a la amputación de manera diferente, presentando fuerzas con diferencias significativas en comparación con los no amputados. Al confrontar los datos de la literatura y los presentados por este estudio, se puede inferir que los atletas amputados y los no amputados tienen una diferencia considerable con respecto a los valores de FRT mediolateral, FRT anteroposterior y duración del soporte, cuando los amputados apoyan el puntapié de fútbol requieren uso de muletas Una mejor comprensión y monitoreo del gesto deportivo de patear en el fútbol de personas con amputaciones necesita más estudios para aumentar la calidad de vida y el rendimiento de los atletas.

Palabras clave—amputado, fútbol amputado, fuerza de reacción del suelo, puntapié.

I. INTRODUCTION¹

The enhanced profile of the Para-Olympics and the consequent development of elite sport for athletes with special needs have not been fully addressed in sport sciences and specifically by the field of biomechanics [1, 2, 3, 4]. Soccer is a sport with a greater number of practitioners in the world, especially in Brazil, becoming the main target of a scientific study [5]. The performance evaluation of tactical and physical condition of players during a soccer match is understood as the study of the game form watching the activity of players and teams, comparing results before and after training, and can be applied to several sports [6].

The speed and agility are cited in the literature as important components of the physical performance of a soccer player. At one point the game will be faster to reach the ball and be more agile avoid a possible collision with an opponent and contribute to the success of the player in their actions [7]. The capacity to accelerate is the component you most interested in the question regarding speed, once the player undergoes several changes during the course of play, the accelerative component should remain stable. By then agility means the ability to perform trajectory deviations with less impairment in their speed [8, 9]. The speed and agility are two qualities of performance that require specific evaluation and is generally assessed on a short distance (5m to 20m) [7, 9].

The amputation of limbs of the human body causes a significant impact on several levels. From the physical point of view their area biomechanical changes that influence their movement, static and dynamic balance, postural changes and transfers, increased metabolic rate, and possible phantom limb syndrome [10]. These changes modify the psychosocial status of the person leading to reduced self-esteem, participation in activities in their community and quality of

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life and may be associated with significant morbidity, disability and mortality. The characteristics of human walking are defined, systematic, that may vary their magnitude depending on motor development, disease and postural imbalances inherent to the human being. The different strategies adopted by individuals are important forms of assistance for the sporting gesture of kick, gait and needs to be better investigated and its possible asymmetries [11].

The adapted sports appeared in the postwar period, as a service to reintegrate the many amputees and spinal cord injuries resulting from fighting. The sports activity for people with disabilities was developed with the objective to be rehabilitative and recreational, however, for some, evolved into the competitive environment [12].

Physical benefits such as improved motor skills, developing the organo-functional potential, stimulation and strengthening of muscle groups are some examples of the benefits achieved with the sport. Psychosocial benefits are also important, as the socialization and the ability to feel movements that are often prevented by physical environmental and social barriers [13]. Among the team sports stands amputee soccer. This mode is a variation of conventional soccer, where only athletes who have a limb amputee, either lower or higher (for goalkeepers) may participate [1, 14]. Not yet been enough studies showing the gain in muscle strength in the amputated limb to soccer practice, but it is evident that athletes who play soccer have a gain in improving balance and gait quality [2, 15].

According to the Brazilian Association of Sports for the Physically Handicapped, Brazil competes in the World Cup Amputee since 1989 and always ranked among the top four of the competition [12]. This demonstrates that the formation of high-performance athletes in amputee soccer involvement of technical, tactical, physical, individual and collective aspects is necessary, both by players and their coaches. The scientific study of these variables, including speed and agility in elite athletes may show an ideal way to improve skills in sport, focusing on facilitating and training.

Due to a complex system of neural control, the human gait is characterized by smooth, regular and successive. The movement is a dynamic process that begins with registration and activation command central nervous system (CNS), followed by the transmission of the electrical signal to the peripheral nervous system and muscle contraction that develop strength, adjustment of forces, movement of segments and finally the generation of ground reaction force (GRF) [16, 17].

Biomechanics is characterized by its interdisciplinary nature, which makes use of the concepts of mechanics in the study of biological systems. The mechanics is the field of science that studies the response of the body to the application of external forces providing a description, analysis and interpretation of the movements of human body segments, through synergic application of concepts from various fields of studies [18, 19].

With regard to external forces, the GRF is the external force most commonly investigated in gait analysis. GRF is a force that acts of the contact surface (ground) to the object (in this case, the human body) in which it is in contact. This force is a result of muscle actions and body weight transmitted through the feet, and the direction and magnitude of GRF exactly equal to the magnitude and direction of motion of the mass center of the body [20].

It is well established need to know all the components and all the factors that favor the movements of the kick in amputee soccer. Noting the limitations of previous studies on the selection of homogenous sample (amputation level, time of amputation) there is the need to search for an analysis of motor and sporting movements. Moreover, such study has not been fully investigated in the literature. Thus, the objective of this study was Kinetic analysis of the sporting gesture and not kick in amputees, comparing the GRF behavior, duration of the stance phase during the execution of the kick of amputees and amputees not in kinetic variables of the force platform.

II. METHODS

En esta sección se describirá el sensor utilizado y se detallarán las técnicas empleadas en el desarrollo del software. Este consiste en un procesamiento de los datos obtenidos desde el sensor para visualizar posiciones en el espacio. Luego a partir de estas posiciones se calculan los valores angulares y por último a través de una interfaz gráfica desarrollada quedan de manera accesible para que el especialista realice su análisis.

A. Obtención de las imágenes mediante Kinect®

The study was approved by the Research Committee Ethics of the Universidade Federal de Minas Gerais. The study sample consisted of 60 male volunteers, 30 of them soccer athletes of the Mining Association of Sports Amputee with a lower limb amputation and the amputation time with a maximum of 20 years. The voluntaries had ages between 18 and 50 years old, without neurological disease, and 30 were considered normal (without amputation), between 18 and 50 years old without neurological or orthopedic disease associated. All volunteers are athletes with at least two years of sport practice, in an attempt to minimize the effects of limb dominance, among the amputee athletes there were different levels of amputees from a lower limb.

Each volunteer participated in one data collection session. The individual performed 5 tries to kick a soccer ball (field officer) with the use of crutches (without prosthesis), before performing the kick, the foot contact with the force platform (Fig. 1 and Fig. 2).

There will be a point of aim for the shot to 2 feet apart, with a height of 1 meter from the ground. The ball will be in support of 20 cm. Group 2 amputees will not kick with the dominant limb, performing before performing the kick, the foot contact with the force platform on the platform’s strength (model: OR6-7; manufacturer: AMTI, USA).

The analysis of force-time curves (Ft) were performed with the program Dasylab (V4.01). Filtering amplifier (AMTI) signal, being lowpass of 1 KHz. It will be used during data collection the analog digital converter Data.
Translation DT9800-EC (Data Translation Inc, USA). The anthropometric measurements such as the weight and height of individuals will be measured using a medical scale (model: 31; manufacturer: Filizola) and a stadiometer engaged in this same equipment, with accuracies of 0.1 kg and 0.5 cm, respectively.

**Protocols**

- Eligibility confirmed
- Informed Consent obtained
- Randomization
  - 60 randomized participants
- Interventions – characterization of the participants
- International Physical Activity Questionnaire – IPAQ
- The individual will perform 5 reps of kick a football (field officer) with the use of crutches (without prosthetics)
- Kinetic analysis
- Group transfemoral amputees 30 participants
- Group not amputees 30 participants

Fig. 2. Flow diagram for the procedures for collecting data on kinetic and questionnaires.

The temporary series of GRF were normalized by body weight and then interpolated so that all have the same number of points. The description of the walking pattern is based on the anteroposterior components (Fx), mediolateral (Fy) and vertical (Fz) of GRF, recorded through SIMI Motion Software 7.2. After these data analyzing, the coefficient of variation was calculated by comparing the amputated and non-amputated groups.

**B. Numerical and Statistical Treatment**

The obtained data were reduced to key statistical measures for the descriptive analysis and organized into tables for further analysis and visualization of results. For quantitative variables was verified the data normality by Kolmogorov–Smirnov test. Then we used the Student t-test for independent samples to compare values obtained in each of the variables considered in both groups (group of normal individuals and group of individuals with lower limb amputated). The t-test for non-paired data was used to compare characteristics and the strength of the limbs within each group. These tests are based on the finding of a significant difference between the two averages. We used a 5% level of significance for all tests and the analyzes were performed using the statistical software routines IBM-SPSS version 20.

### III. RESULTS

The data obtained in relation to anthropometric measures such as weight and height of all volunteers, (not amputees and amputees) involved in the study, were not significantly different ($p \geq 0.05$), characterizing the sample as homogeneous in this aspect (Table I).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>AMP 4</td>
<td>30</td>
<td>75.07</td>
<td>2.667</td>
<td>0.652</td>
</tr>
<tr>
<td></td>
<td>NOR 4</td>
<td>30</td>
<td>75.30</td>
<td>2.982</td>
<td></td>
</tr>
<tr>
<td>Weight (N)</td>
<td>AMP 4</td>
<td>30</td>
<td>735.49</td>
<td>25.01</td>
<td>0.685</td>
</tr>
<tr>
<td></td>
<td>NOR 4</td>
<td>30</td>
<td>737.45</td>
<td>27.78</td>
<td></td>
</tr>
<tr>
<td>Height (m)</td>
<td>AMP 4</td>
<td>30</td>
<td>1.71</td>
<td>0.061</td>
<td>0.654</td>
</tr>
<tr>
<td></td>
<td>NOR 4</td>
<td>30</td>
<td>1.72</td>
<td>0.063</td>
<td></td>
</tr>
<tr>
<td>BMI 4</td>
<td>AMP 4</td>
<td>30</td>
<td>25.67</td>
<td>1.193</td>
<td>0.649</td>
</tr>
<tr>
<td></td>
<td>NOR 4</td>
<td>30</td>
<td>25.42</td>
<td>1.192</td>
<td></td>
</tr>
</tbody>
</table>

- Number of patients; ‘obtained by Student’s t-test to compare means;
- ‘Amputee volunteer; ‘Normal volunteer; ‘Body Mass Index

These data indicate a GRF anteroposterior, the Amputee Volunteer (AMP) group showed gains braking (1st peak: -0.151N) and higher thrust (2nd peak: 0.171N) that the group of non-amputees NOR (-0.133N and 0.151N, respectively). What about GRF mediolateral again the AMP group had the best results, as 0.127N, 0.031N while the NOR group, which demonstrates instability and lower body sway during walking by the group of amputees. As for the variable duration of the stance phase, the AMP group obtained more than the Normal Volunteer (NOR) group (AMP: 0.603s e NOR: 0.542s), this means that the group AMP has less reaction time for the kick. The literature shows that the greater reaction time is extremely important during a soccer match (Table II).

### IV. DISCUSSION

To [21] follows the kick of an association of several rotational movements of the joints of the lower limb, resulting in a rotational movement of all the lower segment. Aims to transfer the resulting speed for an external resistor - ball - it will not act as a restraining movement, then forming a chain joint open.
For [22] during the execution of the kick should be noted that some factors are critical, as the balance of the body, the position of the supporting foot, the foot position and strength of touch that prints the ball, so you can obtain a better efficiency. The analysis of the support leg to kick the can infer results in kinetic variables that comprise the skill sport a higher intensity and balance the center of gravity.

The results indicate that the FRS anteroposterior first peak AMP group has lower braking force during heel strike (-0.151N) compared to the NOR group (-0.133). These results can be inferred from the use of the crutch in soccer of amputees who may support some of the weight of the volunteer.

The authors in [23] conducted a study aimed at measuring ground reaction forces produced by the support member of skilled and non-skilled players while kicking with the instep and compare it with the speed of the ball. Including 18 players who were not classified as skilled or three times and kicked a ball with maximum force. Calculated the average speed of the ball and the ground reaction force and found that the ability to make a strong kick is directly related to the approach speed of the player, depending on a great impulse to the ball.

In the results for FRS mediolateral again the AMP group obtained higher value (0.127N) compared with the NOR group (0.031N). These data may reflect greater instability or dislocation (average lateral oscillation of the body, foot positioning).

In [24], the author analyzed the angular positioning of the foot support and its influence in the outbound direction of the ball during the parade kicking in soccer. Nine players juveniles (15 and 17 years) performed three series of six shots on goal - each series for a given location of the goal - with the medial part of the foot and from a distance of 3 meters from the ball. The author could conclude that the four stages for placing the support member classified in the study (heel support phase, a phase in which the member is fully supported phase in which the chute member touches the ball and the instant of exit from the ball), the phase in which the member is fully supported showed the greatest contribution to the angle of the ball. The author also states that there is slight variation in the angle of position of the foot support during the execution of the movement, or fixed heel, the position of the support member tends to remain fixed to the end of the chute.

One should remember that the movements of the arms serve to balance the body and that they are contributing to the torque movement on the lever body. In the amputee soccer where one makes use of crutches is a division of balance and center of gravity.

The authors in [22] also believe that when the arm is kept away ensures the maintenance of equilibrium. The equilibrium is unstable at the time of execution of the kick, and to put your foot far behind and away from the ball, when you start the movement, the athlete will design your center of gravity back and touch the ball will be done from the bottom up with a small amount of force and it tends to be high.

When compared to the duration of the stance phase of the AMP group presents (0603) while the NOR group (0542) thus we can infer that the longer the soil is the lowest reaction time for the kick.

At work [25], it was the study of the characteristics of ground reaction force of soccer players. The analysis was done during a normal kick approach running. Participants were 20 players of the national team of Italy and 40 players with a high skill level. We used a dynamometric platform that analyzed the reaction force in different directions of approach running and positioning the support member. The results showed that during the support phase progression of force application showed a lower speed than during the impact and the authors concluded that during the stance phase of the body produces a reaction force from the ground consisting of vertical and horizontal strength and there are differences in the patterns of ground reaction force between professionals and other players, and repetitive patterns of professional and mature.

When analyzing the strength of the vertical variable P1 and P2 no significant difference (p ≥ 0.05), demonstrating that both groups remained with the support member to the ground during the time spent by a similar (and output foot force against leaving the ground during walking).

The kick with the instep needs a lever formed with the entire leg, which is formed from the hip to the foot extended. Later the body weight is firm on the supporting leg slightly bent, with your foot pointing forward and to the side of the ball. The leg that will strike the ball should leave behind, semi flexed, balancing back and forth in the vertical plane like a pendulum. Thus the body should be slightly tilted back, the arm opposite the kicking leg must be elevated laterally, and the other arm must be along the body, facilitating balance and gaze tracking the ball from the entrance to the touch and finishing the continuing movement to the movement of the leg attack [26, 27].

A. Study Limitations

This study faced important limitations related to the size of the sample group, the reduced patients number narrows the results just to the population in question.

Another significant limitation is the difficulty of comparing and validating the results due the lack of prior studies related to the kinetics analysis of the sporting gesture of amputee soccer.

Since the volunteers have diverse levels of amputation, this can influence the GRF inference in the kick sporting gesture.

V. Conclusion

Therefore, this paper shows it is possible to point out that the evaluated athletes adapted to amputation in different forms, presenting forces with significant differences when compared to the individual not amputated. Confronting the data of the literature and those presented by the study, it can be inferred that, between amputated and non-amputated athletes, there is a considerable difference in relation to the values of mediolateral GRF, anteroposterior GRF and duration of support, in which the support for the soccer kick of amputees occur with to the use of crutches.

For better monitoring and understanding of the sporting gesture of kicking in the soccer of amputees, it is necessary to elaborate more studies to increase the knowledge about
this reality, in order to increase the life quality and performance of the athletes.

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REFERENCES


