Characterization of professional soccer players' muscle performance*

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ABSTRACT

Introduction and objective: The association of muscular performance with risk of injury and functional performance in different sports has been reported in numerous studies in the literature. However, there is a paucity of data that characterizes the muscular performance in Brazilian professional soccer athletes. Therefore, the objective of this study was to make a descriptive analysis of parameters related to the muscular performance of this population. **Methods:** The sample of this study was composed of 117 athletes belonging to professional soccer clubs in Minas Gerais State. In order to evaluate the muscular performance of the athletes, an isokinetic dynamometer was used and the tests involved maximum voluntary contractions of the selected muscles. Hip abductors and adductors were assessed at the speeds of 30º/s, 60º/s and 120º/s; knee flexors and extensors at 60º/s, 180º/s and 300º/s; and ankle dorsiflexors, plantarflexors, invertors and evertors at 30º/s, 60º/s and 180º/s. Descriptive statistics were used to present the normative data and paired t-tests were used to identify significant differences between legs considering the parameters evaluated in this study. **Results:** This study generated normative data to characterize the profile of Brazilian professional soccer players relative to their capacity of producing torque, muscle work and power. Significant differences were observed between legs considering some of the study's variables. **Conclusion:** The established normative data can be used as reference values in the prevention, training and rehabilitation of the athletes. In addition, these data may be used as reference for future studies with the objective of testing the association between muscular performance and incidence of injury in soccer practice.

Keywords: Normative data. Isokinetic evaluation. Soccer. Lower extremities.

INTRODUCTION

Soccer is a sport which deserves attention for its popularity as well as the great number of injuries derived from its practice[1-4]. According to Keller *et al.*[5] this sport is responsible for 50 to 60% of all sportive injuries, being responsible for a high rate of athletes' time out of games and training. Such time out results in economical harm both for the athletes and their clubs[3-4]. International studies report expenses at around 20 million of dollars with professional soccer players put aside due to injuries derived from its practice[3-4]. In addition to economical harm, the decrease in sports performance is also a consequence derived from these injuries and the time out resulting from them[2,4,6]. Other studies have also reported high recurrence of soccer injuries, which results in longer periods of time out and even more accentuated performance decrease[4.6]. The understanding of the main risks associated with these injuries would enable the development of prevention interventions, decreasing hence the number of injuries and their negative consequences for the clubs as well as the athletes[1-4,7].

Injuries associated with soccer practice may occur in several body joints[2,4,8]. According to Heidt *et al.*[9], 68-88% of these injuries occur in the knee and ankle joints. The main mechanism associated with soccer injuries is indirect, that is, independent from physical contact among players[1-2,4]. The associated factors to this mechanism may be extrinsic and/or intrinsic to the athlete[2,5]. The main extrinsic factors are the training site, the equipment used and environmental conditions[1-2]. The intrinsic factors include muscular performance which may be characterized by the capacity of the muscles to produce torque, work, power and resistance. Several studies have been demonstrating that alterations in these parameters are associated with sports injuries and decrease in functional performance[1-2,7,10,12-13]. The main alterations mentioned as risk factors for injuries in soccer are asymmetries in the muscular performance parameters between dominant and non-dominant limb as well as alterations in the torque relationship between antagonist muscles[1,5,9-10,13]. Therefore, the identification of these risk factors would enable the development of a prevention work specific to soccer players with the aim to correct the observed alterations.

Asymmetries or deficits in maximal torque production between legs above 10% have been frequently associated with muscular injuries[1,8,14]. Several studies have demonstrated that soccer players who suffered indirect injuries in the knee presented torque deficits of the flexor-extensor muscles in the involved limb when compared with the counterlateral one[1,8,10]. Deficits in maximal work and mean power variables can be also associated with the incidence of muscular injuries[5,11]. The occurrence of these asymmetries would indicate an increased risk of injury for these athletes[1,8,10].

Another parameter which has been widely mentioned by several authors as being a strong risk injury-prone is the torque relationship between antagonist muscles (agonist/antagonist relation)[1-2,7,10,12-13]. Such relation is the ratio of the maximal torque produced by the agonist muscles by the maximal torque produced by the antagonist muscles. The literature reports optimum ratios between muscles which cross the main body's joints and have been demonstrating that deviations in these ratios are associated with muscular and joint injuries[1-2,7,10,12-13]. The literature shows for instance that for the knee joint in the 60º/s velocity, the optimum ratio between maximal torque of hamstrings and maximal torque of quadriceps is at an average of 60%. Changes in this ratio make soccer players prone to both injuries in the knee joint and strains in the hamstring muscles[1-2,4,10,13]. Likewise, imbalances in the torque production between dorsiflexors and plantarflexors and adductors and abductors constitute in a risk factor for ankle and hip injuries respectively[14-15]. Due to the existent association between imbalances and muscular injuries, the investigation of the torque relation

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between antagonist muscles would enable to detect a possible risk factor for injury in professional soccer players.

The parameters associated with muscular performance which have impact in the occurrence of injuries in soccer can be evaluated with the use of isokinetic dynamometry[10-11,16]. In sports environment, such instrument has been used for the evaluation of elite athletes, both in research and clinical practice, once it provides accurate data concerning muscular performance of this population. Nevertheless, the lack of studies which characterize the profile of Brazilian athletes concerning muscular performance makes the interpretation and use of these results difficult. The establishment of normative data concerning capacity of torque production, work and power of professional soccer players may be the grounding for clinical practice as well as subsidize scientific research. These data may be used as reference values in prevention, training and rehabilitation of athletes, besides serving as reference for future studies which have the aim to relate muscular performance parameters with incidence of injuries in soccer. Therefore, this study has the aim to establish normative data concerning muscular performance of professional soccer players. The profile of the athletes concerning torque production capacity, work and power was outlined through isokinetic evaluation. The torque relationship between the agonist and antagonist muscles of the hip, knee, talocrual and subtalar joints was also established. Moreover, a comparison between legs in each evaluated parameter was performed with the aim to verify possible asymmetries derived from soccer practice.

METHODS

Sample

117 Brazilian professional soccer athletes who belong to the América Futebol Clube, Clube Atlético Mineiro and Cruzeiro Esporte Clube from the Minas Gerais State participated in this study. Mean age of the players was 24.67 ± 4.06 years, mean height was 1.78 ± 0.7 m and mean weight 74.6 ± 7.16 Kg. From the 117 athletes, all participated in the knee evaluation, 52 the hip and 39 the talocrural and subtalar joints. Defenders, midfielders and forwards on the field positioning took part in this sample. Players who presented history of injury in the lower limbs which could alter performance in the tests were excluded.

Instruments

An isokinetic dynamometer (*Biodex System 3 Pro*), an electromechanical instrument controlled by a microcomputer was used in order to evaluate muscular performance of the athletes in the hip, knee, talocrural and subtalar joints.

Procedure

The evaluations were conducted in the Laboratory of Human Performance of the Physical Education, Physical therapy and Occupational Therapy of the Federal University of Minas Gerais, during the pre-season of years 2000-2003.

The athletes showed up suitably dressed for the tests performance and were instructed on their procedures. Prior to the evaluation, the athletes were weighted on a calibrated scale and this weight was fed to the isokinetic program. Afterwards, the athletes performed five minutes of warm-up exercises in an ergometric bicycle and stretching exercises for the lower limbs muscles (quadriceps, hamstrings, adductors and sural triceps). Stretching consisted of four sets of twenty seconds and was bilaterally performed[8].

After stretching, the athletes were placed in the isokinetic dynamometer for tests performance. Three sets in each velocity of the test were performed in order to familiarize the athletes with the instrument Evaluation of muscular performance consisted of alternated concentric contractions of the tested muscles groups and the athletes received verbal encouragement in order to perform the maximal strength during the test. All evaluations were bilaterally performed.

In the hip joint the performance of the adductor and abductor muscles was evaluated in the standing position, with 0º of hip flexion. In order to have this evaluation, the dynamometer axis was aligned with the antero-superior iliac spine. The test velocities were 60º/s, 120º/s and 240º/s. In order to have the knee extensor and flexor muscles evaluated, the subjects were placed in a sitting position with 85º of hip flexion and with the axis of the instrument aligned with the lateral condole of the femur. The test velocities were 60º/s, 180º/s and 300º/s. In the talocrural joint, the performance of the dorsiflexor and plantarflexor muscles was evaluated, in the velocities of 30º/s, 60º/s and 180º/s. The subjects were placed in a sitting position, with 70º of hip flexion and knee flexion between 20-30º and the axis of the instrument was aligned with the lateral malleolus. The inversor and eversor muscles were also evaluated in the 30º/s, 60º/s and 180º/s velocities. The test was performed in a sitting position, with hip flexion of 70º; knee with flexion between 30-45º and ankle with 35º of plantar flexion. The dynamometer axis was aligned with the lateral malleolus. According to the manufacturer's suggestion, all muscles were evaluated in all available ADM in the joint.

The used protocols for evaluation of each joint consisted of five sets in low velocity, ten sets in medium velocity and fifteen sets in high velocity, according to the dynamometer manufacturer's recommendations. The athletes had a resting period of ten seconds between the evaluations performed in each velocity.

Data reduction

The muscular performance parameters described in this study were maximal torque, maximal work, empirically considered as the area under the strength curve and dislocation, and mean power, normalized by the body mass. Such procedure of normalization was performed by the dynamometer's software using the weight values of each athlete. In addition to these parameters, the relationship between agonist and antagonist muscles of each tested joint was characterized. All parameters analyzed in the study were calculated by the isokinetic dynamometer's software and registered in a standardized report generated by it. Prior to the calculation, a windowing software filter option was selected, according to the manufacturer's instruction for decrease of possible artifacts in the collected data.

All parameters were evaluated in the three test velocities in all joints, except for mean power which was described only in the low velocity. This parameter was not described in the medium and high velocities once it is influenced by muscular fatigue derived from higher number of sets performed in these velocities.

Statistical analysis

A descriptive analysis was used in order to characterize the ratio among individuals in the maximal torque and work variables, mean power and agonist-antagonist ratio normalized by the body mass. In addition to the mean and standard deviation, the reliability interval of 95% was determined for the means of all variables. Paired T-tests were used with the purpose to verify significant differences between dominant and non-dominant legs of the athletes considering the means of the variables analyzed in the present study.

RESULTS

All the evaluated athletes were able to perform the tests they were submitted to. The muscular performance of the athletes is represented through the means as well as the standard deviation of maximal torque, maximal work, mean power variables and the agonist-antagonist relationship.

Hip joint

The values obtained in the evaluation of the adductor and abductor hip muscles in the 60º/s, 120º/s and 240º/s velocities are found in table 1. The paired t-test did not show any significant difference in the analyzed variables when the comparison between dominant and non-dominant legs was performed.

Knee joint

The parameters concerning performance of flexor and extensor knee muscles in the 60º/s, 180º/s and 300º/s velocities are described in table 2. In the knee joint, differences between dominant and non-dominant legs in the three tested velocities were observed. In the 60º/s velocity, the flexor muscles presented higher values of mean power and maximal work in the dominant limb. At 180º/s, differences in maximal torque of flexor muscles as well as in the agonist/antagonist relationship were found. In the 300º/s velocity, significant differences were identified both in maximal torque, maximal work and agonist/antagonist relationship produced by the flexor muscles. In these cases, the highest values were observed in the dominant leg.

Talocrural joint

The values obtained in the evaluations of the talocrural joint in the 30º/s, 60º/s and 180º/s velocities are found in table 3. The paired t-test demonstrated a significant difference between dominant and non-dominant leg only in the maximal work variable of the two muscular groups evaluated at 30º/s. In the dominant leg, the dorsiflexor and plantarflexor muscles developed significantly higher work than in the non-dominant leg.

Subtalar joint

Table 4 shows the values obtained in the parameters of muscular performance of the subtalar evaluation in the 30º/s, 60º/s and 180º/s velocities. The t-test detected a significant difference between legs in maximal torque of the inversors at 30º/s, which was higher in the non-dominant leg. Moreover, the eversors/inversors relationship at 30º/s was significantly higher in the dominant side. Finally, in the 60º/s velocity, the inversor muscles of the dominant side generated values significantly higher of maximal torque. Still at this velocity, maximal work of eversors was significantly higher in the dominant side.

DISCUSSION

The aim of this study was to characterize the muscular performance of professional soccer players, considering parameters of maximal torque, maximal work and mean power of the hip, knee and ankle joints muscles (talocrural and subtalar). In the sports re-

TABLE 1
Mean (standard deviation) of the maximal torque (MT), maximal work (MW), mean power (Pow) variables and maximal torque relationship between abductors (Ab) and adductors (Ad) in the hip joint expressed in %

	60º/s		120º/s		240º/s	
	DOM	Non-DOM	DOM	Non-DOM	DOM	Non-DOM
MT Abductors	217.37 ± 40.61	212.32 ± 35.32	192.15 ± 32.43	191.40 ± 37.21	151.78 ± 61.53	153.97 ± 55.94
MT Adductors	267.93 ± 65.66	270.44 ± 62.47	259.64 ± 64.07	254.82 ± 66.79	192.79 ± 68.20	186.51 ± 70.75
MW Abductors	94.62 ± 33.93	96.02 ± 34.90	137.68 ± 33.70	92.39 ± 28.23	45.57 ± 24.72	48.75 ± 23.85
MW Adductors	98.42 ± 28.74	102.97 ± 36.95	116.85 ± 37.82	110.88 ± 37.34	99.32 ± 43.48	95.89 ± 47.57
Pow Abductors	96.01 ± 22.50	94.58 ± 23.60	–		–	
Pow Adductors	112.14 ± 29.26	115.27 ± 31.75	–		–	
Relation Ab/Ad	85.74 ± 26.96	81.44 ± 19.46	79.62 ± 29.60	80.22 ± 27.91	86.07 ± 43.18	94.22 ± 49.76

TABLE 2
Mean (standard deviation) of the maximal torque (MT), maximal work (MW), mean power (Pow) variables and maximal torque relationship between flexors (Fl) and extensors (Ext) of the knee joint expressed in %

	60º/s		180º/s		300º/s	
	DOM	Non-DOM	DOM	Non-DOM	DOM	Non-DOM
MT Extensors	358.13 ± 49.56	358.86 ± 50.83	234.94 ± 25.90	239.81 ± 27.55	180.96 ± 31.19	183.10 ± 29.48
MT Flexors	293.97 ± 64.70	179.67 ± 31.38	150.19 ± 23.13	144.86 ± 21.62*	134.30 ± 23.79	128.32 ± 23.55*
MW Extensors	521.24 ± 111.03	516.48 ± 117.56	365.38 ± 74.06	369.05 ± 77.71	254.14 ± 59.06	257.50 ± 59.15
MW Flexors	293.97 ± 64.71	282.38 ± 65.39*	217.21 ± 46.35	212.45 ± 45.70	157.90 ± 36.94	149.57 ± 37.11*
Pow Extensors	235.09 ± 34.05	235.37 ± 35.86	–		–	
Pow Flexors	132.87 ± 20.12	128.19 ± 20.81*	–		–	
Relation Fl/Ext	82.97 ± 19.11	50.66 ± 9.57	64.37 ± 10.53	60.91 ± 9.96*	75.15 ± 12.55	70.93 ± 13.09*

TABLE 3
Mean (standard deviation) of the maximal torque (MT), maximal work (MW), mean power (Pow) variables and maximal torque relationship between dorsiflexors (DF) and plantarflexors (PF) in the alocrural joint. expressed in %

	30º/s		60º/s		180º/s	
	DOM	Non-DOM	DOM	Non-DOM	DOM	Non-DOM
MT PF	161.46 ± 36.01	156.51 ± 36.22	135.43 ± 32.05	131.90 ± 29.97	76.28 ± 17.61	75.68 ± 16.38
MT DF	53.81 ± 11.31	53.64 ± 12.79	44.33 ± 10.97	42.94 ± 10.91	27.97 ± 7.53	27.13 ± 8.22
MW PF	86.84 ± 30.08	79.21 ± 25.70*	80.74 ± 29.87	79.21 ± 25.70	45.03 ± 18.18	43.96 ± 16.27
MW DF	32.97 ± 11.43	26.67 ± 9.51*	27.51 ± 11.28	26.67 ± 9.51	14.98 ± 7.26	13.32 ± 5.21
Pow PF	50.19 ± 14.64	49.35 ± 15.30	–		–	
Pow DF	17.14 ± 5.35	17.14 ± 5.74	–		–	
Relation DF/PF	34.56 ± 9.04	35.43 ± 11.75	34.00 ± 9.61	33.57 ± 11.31	37.78 ± 11.42	37.12 ± 11.83

TABLE 4
Mean (standard deviation) of the maximal torque (MT), maximal work (MW), mean power (Pow) variables and maximal torque relationship between eversors (E) and inversors (I) in the ankle joint expressed in %

	30°/s		60°/s		180°/s	
	DOM	Non-DOM	DOM	Non-DOM	DOM	Non-DOM
MT Eversors	38.48 ± 9.96	37.54 ± 10.18	33.91 ± 78.11	32.19 ± 10.42	24.24 ± 5.17	23.33 ± 7.04
MT Inversors	34.96 ± 8.77	37.54 ± 8.44*	34.96 ± 8.77	32.46 ± 8.55*	27.76 ± 6.03	25.82 ± 5.93
MW Eversors	21.25 ± 6.02	20.34 ± 6.39	19.94 ± 5.70	17.68 ± 6.91*	12.88 ± 4.28	12.19 ± 5.09
MW Inversors	20.11 ± 5.86	19.93 ± 5.99	19.62 ± 5.90	18.38 ± 6.15	14.94 ± 4.40	25.82 ± 5.93
Pow Eversors	10.98 ± 2.99	10.79 ± 31.28	–		–	
Pow Inversors	11.52 ± 3.56	11.15 ± 3.20	–		–	
Relation E/I	103.78 ± 22.03	102.13 ± 27.13*	100.61 ± 26.28	100.84 ± 27.70	90.01 ± 22.22	92.04 ± 26.32

habilitation field, the establishment of normative data concerning muscular performance may be useful in the prevention, training and rehabilitation of athletes. Several international studies have characterized muscular performance of soccer athletes, especially concerning their maximal capacity of muscular torque production[9,16]. However, the use of these results as reference for Brazilian soccer athletes would not be optimum, once these data are specific to each population. In Brazil, there is a need for studies with the purpose to characterize muscular performance of soccer players; besides that, the studies found are restricted to the evaluation of only one joint of the lower limb, considering only the maximal torque parameter. Alonso *et al.*[16] only reported data concerned with muscular performance of the ankle joint of youth soccer players, though. Pinto *et al.*[11] evaluated Brazilian professional soccer players and only reported knee flexor and extensor torque at 60°/s. Nevertheless, these authors did not normalize the data by the body mass, which hampers the comparison of results.

The torque values obtained by the athletes evaluated in this study are higher than the ones reported by other research which evaluated the muscular performance of individuals of the ordinary population[9,14]. Possibly, this difference in muscular performance of the athletes is associated with great physical demand imposed by soccer's professional practice. In this case, not only the sport itself, but also its necessary training for the athlete's preparation for games, such as training on the field or performance of weight training, may explain better muscular performance of athletes when compared with the ordinary population. The Brazilian athletes presented better muscular performance at 60°/s for the flexion and extension movements in the knee joint in comparison with soccer players evaluated in international studies[3,17]. In the 180°/s velocity, only an improvement of the Brazilian athletes in the knee extensor muscles was observed[13]. The found values for maximal torque of the flexor muscles in this population are lower than the ones reported in international studies[13,19]. These differences observed between the results could be explained by methodological differences such as the type of dynamometer used and/or positioning of athletes during evaluation. Another possible explanation would be the training specificities inside and outside the field (weight training) which can exist among countries or among different soccer clubs.

The eversor and inversor muscles performance of the ankle at 30°/s of the evaluated athletes in this study was lower than the one reported by Alonso *et al.*[16] in their study conducted with Brazilian athletes from the youth category. This worse performance can be due to the difference in the measurement instrument used, in the positioning of athletes during the test, or to possible differences in training demand imposed to players of different categories. In the study conducted by Alonso *et al.*[16] the athletes were submitted to evaluation in isokinetic dynamometer *Cybex* 6000 and positioned in dorsal decubitus, with knee flexion of 120°, hip flexion of 45° and ankle in neutral position. Comparisons with other studies involving hip and ankle joints were not possible due to methodological differences, such as test protocols velocities as well as lack of normalization of tested variables by body mass.

The values of maximal torque between agonist and atagonist musclesrelation found in this study were able to be compared only with data of soccer players found in the literature concerning knee joint at 180°/s and in the subtalar one at 30°/s. As for the knee, the value presented in this study was lower than the ones presented in international studies[9,17]. The literature shows that ratio values below 60% have been associated with hamstrings strains[1,14,17]. However, although the ratios found in the present study are lower than the ones found in international studies, the athletes with no history of injury evaluated presented values of 64.37% in this ratio. These findings show that these athletes have a suitable agonist-antagonist relation in the knee joint for sports practice. In the subtalar one, the ratio between eversors and inversors at 30°/s, presented in this study was of 103%. Such value is higher than the one found in the study by Lentell *et al.*[4] and similar to the result reported by Alonso *et al.*[16]. In the former, held in the U.S.A. with normal individuals, the value found was of 88%, while in the latter, held with Brazilian young soccer athletes, it was of 96%. The literature shows that an optimum ratio of maximal torque between ankle inversors and eversors would be close to 100%, regardless of the kind of physical activity practiced[16]. Thus, the Brazilian professional soccer players with no injury history tested in the present study, have a suitable agonist and antagonist ratio in the subtalar joint for physical activity practice.

The comparison established between dominant and non-dominant limbs of the athletes determined significant differences only in some variables. Whenever present, these asymmetries were derived from worse performance of the non-dominant leg, except for the maximal torque of the inversors at 30°/s which was lower in the dominant leg. This result suggests a possible influence of dominance in muscular performance. Despite this influence, the asymmetries observed in this study did not surpass 10%. According to the literature, only asymmetries higher than this value are considered risk factor for injury[1,17], showing hence, that the Brazilian professional soccer players with no history of injury evaluated in this study seem to present a level still safe of asymmetries between limbs. Once symmetry maintenance between limbs is so important for injury prevention[1,17], early detection of possible asymmetries would contribute for training development in an attempt to reduce them.

The present study enabled the evaluation of maximal work and power, which are usually neglected in the majority of studies about muscular performance[2,6-7,11]. These variables, as well as maximal torque, are relevant to be evaluated, since deficits in them have been associated with incidence of muscular injuries during games[5,11]. Moreover, deficits in power in low velocity could influence performance in the sprinting movement during a game. A limitation of the present study was only the concentric evaluation of muscular performance. Deficits in eccentric torque production have been already associated with muscular strains[7]. Therefore,

the development of studies which describe the profile of athletes concerning eccentric muscular performance would also aid programs of injury prevention in soccer. In addition to that, new studies have been developed with the purpose to characterize isokinetic muscular performance according to the players' positions on the field, once athletes who play in different positions have specific demand and training which can interfere in muscular performance variables.

CONCLUSION

The obtained results in this study provide reference values of the isokinetic muscular performance concerning not only the capacity to generate torque and maximal work but also mean power of professional soccer players. Besides the characterization of muscular performance, the present study established a comparison between dominant and non-dominant limb. In this comparison, asymmetries both in the knee and ankle joints were observed. Whenever present, these asymmetries were derived from worse performance of the non-dominant leg, suggesting hence a possible influence of dominance in muscular performance. Normative data enable the comparison of results of the test of an athlete with the reference values of his group, in a trial to establish a level of muscular performance to be reached with training or rehabilitation. Moreover, these data may channel the development of studies which try to relate muscular performance parameters with injuries in this sport. These studies would lead to the development of therapeutic interventions with the aim to prevent injuries and their reoccurrences.

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