MAZUQUIN, B.F.; BELA, L.F.D.; PELEGRINELLI, A.R.M.; DIAS, J.M.; CARREGARO, R.L.; SELFE, J.; RICHARDS, J.; BROWN, L.E.; MOURA, F. A.; CARDOSO, J.R. Torque-angle-velocity relationships and muscle performance of professional and youth soccer players. International Journal of Sports Medicine, 2016.

Abstract

Soccer matches consist of a variety of different activities, including repeated sprints. Time to attain velocity (TTAV), load range (LR) and the torque-angle-velocity relationship (TAV_{3D}) represent an important measurement of muscle performance however there are few studies related. The aim of this study was to compare these outcomes between soccer players of different age category. Seventeen professional (PRO) and seventeen under-17 (U17) soccer players were assessed for concentric knee flexion/extension at 60, 120 and 300 °/s. For the extensor muscles, differences were found in favor of the U17 group for TTAV and LR outcomes at 120 °/s, however, the PRO group maintained higher torques in both movement directions in comparison to the U17 in TAV_{3D} evaluation. These results suggest that muscle performance of the PRO group is more efficient than the U17 group.

INTRODUCTION

Soccer matches consist of a variety of different physical demands and activities, including running which comprises repetitive periods of sprinting and walking [2, 10]. Peak torque is the most commonly reported outcome measure when using an isokinetic device to assess strength of the lower limbs [1, 17, 22]. Time to attain velocity (TTAV) (the time to reach a target velocity) as well as load range (LR) (the capacity to maintain a given velocity during an isokinetic test) have been considered an important measurement of muscle performance and could help to discriminate player status following training intervention strategies [4, 7, 8, 30].

Another feature of muscle performance, which cannot be observed when single values of peak torque, average power or total work are reported, is the joint torqueangle-velocity relationship (TAV_{3D}). The TAV_{3D} represents the dynamic behavior of a muscle and can be applied to training [22] as a complement to the length-tension and length-velocity relationships, providing a more comprehensive assessment of functional capacity [19, 23].

During a soccer match, elite soccer players perform 150-250 brief intense actions, half of them are shorter than 10 m and almost all actions are shorter than 30 m [11]. This demonstrates the importance of the player being able to develop strength in the speed required to achieve the goal of the motor task. It is known that dominant limb and age can influence these outcomes [21], mainly between young players due to teenage years promote changes in growth and development [9], where the most advanced present greater muscle strength [29].

There is no consensus about the relationship between the isokinetic outcomes and functional testing. Some studies showed that the flexors/extensors peak torque, evaluated at different speeds, are not good predictors for the performance of functional tests as one-leg-hop, triple-jump, vertical-jump, one-leg-rising, square-hop and repeated-sprint ability [11, 27, 28]. While Cabri *et al*. [6] found a strong correlation (*r*=.77) between the distance of the kick and peak torque of knee extensors and flexors.

However, little is known about the behavior of TTAV, LR and TAV_{3D} between soccer players of different age category [15, 21]. Thus, TTAV and LR may provide additional information regarding the effects of training programs, helping coaches and athletic trainers assess specific goals according to the needs of each player [5]. Thus, the aim of this study was to evaluate, describe and compare TTAV, LR and TAV_{3D} between soccer players of different age category.

MATERIALS & METHODS

A total of 34 soccer players, who were preparing for regional and national competitions, volunteered to participate. The groups consisted of 17 professional players (PRO) of the First State League and seventeen under-17 (U17). The sample size was calculated through G*Power 3.1.9.2 [13] using a two-tailed Student *t* test to find differences between groups, effect size estimated as 0.8, $\alpha = 0.05$. Thirty-four subjects were necessary for a power of 82%.

The inclusion criteria were: absence of lower limb injuries in the preceding three months, age over 20 years for the PRO group and age between 15 and 17 years for the U17. The athletes' characteristics are presented in **TABLE 1**. All testing occurred during the pre-season, one month before the season started. All participants read and signed an informed consent prior to the evaluation, this study meets the ethical standards of the journal [16] and all procedures were approved by the Universidade Estadual de Londrina Ethics Committee (#055/2012).

Evaluation procedures

All testing was carried out by the same investigator, in the Laboratory using a Biodex System 4® Dynamometer (Biodex Medical System Inc., Shirley, NY). Contraction mode was concentric isokinetic, at 60, 120 and 300 °/s, for knee flexion/extension. Athletes were instructed not to train on the day of testing or the afternoon of the day before. The testing protocol was characterized by one set of five repetitions at each velocity, in random order, with a rest period of 90 seconds between sets [31]. Prior to the isokinetic test, participants warmed-up on a stationary cycle for 10 minutes. They were then positioned on the seat of the dynamometer, and stabilized by belts around their trunk, pelvis and thigh. Hip flexion was set at 85° and the dynamometer axis was aligned with their lateral femoral epicondyle. The ankle pad was positioned just above their medial malleolus [20]. All calibration procedures and gravity correction procedures followed the manufacturers' instruction manual [3]. Range of motion was set from 90° of flexion to 0° extension, avoiding knee hyperextension. They were instructed to perform with maximum effort during all repetitions while verbal encouragement and visual feedback were provided. For reliability purposes, a coefficient of variation less than 10%, for each set, was considered acceptable [26].

Prior to data collection, familiarization was conducted at each speed with one set of 10 repetitions at 300 °/s and 120 °/s with 90 seconds rest . At 60 °/s , only one set of 5 repetitions was performed (because of the difficulty of the speed).

Data Analyses

Isokinetic data processing was performed with specific *Matlab*® algorithms. TTAV and LR (in milliseconds) were calculated as mean values from all five repetitions at 60, 120 and 300 °/s . TTAV considered the initial phase of ROM, representing the time taken to achieve the isokinetic velocity phase. From this, LR was calculated as the duration of the isokinetic phase when the predetermined velocity was maintained till beginning deceleration [6]. Sampling frequency was 100 Hz.

To create the TAV_{3D} surface maps, the *surf* mathematical function from *Matlab*® was used. All five repetitions of each velocity were interpolated according to time duration. The algorithm estimated the intrinsic geometry by considering torque (z-axis), joint angle (x-axis) and velocity (y-axis) in the same time frame. The z axis defines the map height in relation to strength intensity while the x and y axes shape boundaries of the surface. The dark grey color (**FIGURES 1** and **2**) demonstrates higher torque while light grey is lower torque. The color intensity is proportional to each surface throughout the ROM.

Statistical analyses

The Shapiro-Wilk test was used to verify data distribution, then the Mann-Whitney test was applied for comparisons between groups and the Wilcoxon test for comparison between the dominant and non-dominant legs. Statistical significance was set at 5% and all analyses were performed with SPSS version 22.0 (IBM SPSS®, Armonk, NY, USA).

RESULTS

No statistically significant differences were found between the dominant and non-dominant legs in both groups. All statistical differences between the groups were observed at 120 °/s for extension. The U17 group took longer to perform the repetition when compared to the PRO group, U17 total time: 840 ms; PRO total time: 820 ms; *P*=.03. Still, the U17 group had lower TTAV (*P* <.001) and greater LR (*P*=.005). However, for other outcomes, such as peak torque and total work at 120 °/s (**TABLE 1**), the PRO group showed better results. That occurred despite the U17 group's ability to maintain the speed longer when compared to the PRO group. However, the latter generated more torque and work in less time. More details can be seen in **TABLES 2 - 4**.

There were no differences for any other outcome. **FIGURES 3** and **4** depict the maintenance of speed throughout the entire ROM. However, there were no differences between groups.

For TAV_{3D} analysis, the PRO group leg extension exhibited a larger dark grey area, extended until approximately 250 °/s , compared to the U17 group, which only extended to approximately 200 °/s. Further more, at the end of the ROM (joint angle of 0 º) the PRO group demonstrated greater values than the U17 group. The TAV_{3D} surface maps for extension for both groups are shown in **FIGURE 1**.

The flexion maps demonstrated different curves than extension, maintaining areas of high torque for a longer ROM and without a prominent peak torque. The PRO group had higher torque areas and, once again, during the final stage (joint angle of 90°) , presented even smaller areas of lower torque when compared to extension. The TAV_{3D} surface maps of knee flexion for both groups are shown in **FIGURE 2.**

DISCUSSION

This study only observed a statistical difference for knee extension TTAV and LR (120 °/s), with lower values for the U17 group. The behavior of each muscle group, as presented by the TAV_{3D} surface maps, demonstrated that the PRO athletes were able to maintain higher torques during the test.

Differences in strength capacity (of extensors and flexors muscles) reported by peak torque have previously been shown between these two age category groups [18, 25]. However, the results of the present study demonstrate that despite strength differences and physical demands in a soccer match [14], athletes of different ages have a similar ability to develop acceleration and knee joint velocity, with the exception of knee extension at 120 °/s. These muscles have an important role and may be associated with jumping, changing direction while running and kicking as well as movements where success is partially related to velocity [12].

The results demonstrate that the U17 group is able to maintain a required velocity for longer durations (larger LR), and therefore, it was expected that this group had also a lower TTVA because these outcomes are inter-related [5, 8, 19]. Le Gall *et al.* [23] stated that the quadriceps femoris presents maximum development at the age of 21 years while thereafter, performance seems to remain stable. Contrary to this, the hamstrings achieve their maximum improvement at the age of 16 years [25]. Thus, the fact that the majority of subjects in the U17 group had already reached this age (16 years) may explain the results for the flexors, because there was any difference between groups. For the results found for the extensors, the TVA_{3D} surface map provides valuable information and a more detailed biomechanical analysis, because, although the U17 group shows better results for TTAV and LR, the PRO group maintained higher torques in both movement directions in comparison to the U17. That is, the muscle performance of the PRO group is more efficient than the U17 group. This conclusion can only be taken when analyzing the TVA_{3D} surface maps, hence it allowed for a broader view of the isokinetic assessment [17, 19, 23].

This study has some limitations, such as the maturational status of athletes and skill levels. It is suggested that in future studies the athletes should be separated into groups according to both characteristics. In addition, it is known that isokinetic evaluations (which are the gold standard for muscle performance) are not always available in practice. Several studies have related isokinetic results with field tests [11, 27, 28], though none correlated the outcomes in this study with such tests, so further studies with these objectives are needed. Furthermore, the recommended rest periods between strength training could not be done due to logistical issues of the team. This may have biased the results. Finally, data presented here is representative of just one soccer team so caution should be exercised when extrapolating to other populations.

CONCLUSIONS

For the extensor muscles, differences were found in favor of the U17 group for TTAV and LR outcomes at 120 °/s . However, the TAV_{3D} evaluation demonstrated that the PRO group maintained higher torques in both muscles in comparison to the U17.This suggests that muscle performance of the PRO group is more efficient than the U17 group.

Practical Implications

- The evaluation of outcomes such as TTAV and LR can provide information on muscle efficiency of athletes and serve as a support for strength training prescriptions. - Surface maps improve understanding of muscle behavior and allow for a complementary analysis that can support strength training prescriptions.

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