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4 youth soccer players. International Journal of Sports Medicine, 2016.

5

6 **Abstract**

7

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

19

20 **INTRODUCTION**

21

22 Soccer matches consist of a variety of different physical demands and activities,
23 including running which comprises repetitive periods of sprinting and walking [2, 10].
24 Peak torque is the most commonly reported outcome measure when using an
25 isokinetic device to assess strength of the lower limbs [1, 17, 22]. Time to attain

26 velocity (TTAV) (the time to reach a target velocity) as well as load range (LR) (the
27 capacity to maintain a given velocity during an isokinetic test) have been considered
28 an important measurement of muscle performance and could help to discriminate
29 player status following training intervention strategies [4, 7, 8, 30].

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

36 During a soccer match, elite soccer players perform 150-250 brief intense
37 actions, half of them are shorter than 10 m and almost all actions are shorter than
38 30 m [11]. This demonstrates the importance of the player being able to develop
39 strength in the speed required to achieve the goal of the motor task. It is known that
40 dominant limb and age can influence these outcomes [21], mainly between young
41 players due to teenage years promote changes in growth and development [9],
42 where the most advanced present greater muscle strength [29].

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

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

56

57 **MATERIALS & METHODS**

58

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

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

72

73

74

75 Evaluation procedures

76

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

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

97

98

99

100 Data Analyses

101

102 Isokinetic data processing was performed with specific *Matlab*® algorithms. TTAV
103 and LR (in milliseconds) were calculated as mean values from all five repetitions at
104 60, 120 and 300 °/s. TTAV considered the initial phase of ROM, representing the
105 time taken to achieve the isokinetic velocity phase. From this, LR was calculated as
106 the duration of the isokinetic phase when the predetermined velocity was maintained
107 till beginning deceleration [6]. Sampling frequency was 100 Hz.

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

116

117 Statistical analyses

118

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

124

125 RESULTS

126

127 No statistically significant differences were found between the dominant and
128 non-dominant legs in both groups. All statistical differences between the groups were
129 observed at 120 °/s for extension. The U17 group took longer to perform the
130 repetition when compared to the PRO group, U17 total time: 840 ms; PRO total time:
131 820 ms; $P=.03$. Still, the U17 group had lower TTAV ($P < .001$) and greater LR
132 ($P=.005$). However, for other outcomes, such as peak torque and total work at 120
133 °/s (**TABLE 1**), the PRO group showed better results. That occurred despite the U17
134 group's ability to maintain the speed longer when compared to the PRO group.
135 However, the latter generated more torque and work in less time. More details can
136 be seen in **TABLES 2 - 4**.

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

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

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

150

151 **DISCUSSION**

152

153 This study only observed a statistical difference for knee extension TTAV and LR
154 (120 °/s), with lower values for the U17 group. The behavior of each muscle group,
155 as presented by the TAV_{3D} surface maps, demonstrated that the PRO athletes were
156 able to maintain higher torques during the test.

157 Differences in strength capacity (of extensors and flexors muscles) reported by
158 peak torque have previously been shown between these two age category groups
159 [18, 25]. However, the results of the present study demonstrate that despite strength
160 differences and physical demands in a soccer match [14], athletes of different ages
161 have a similar ability to develop acceleration and knee joint velocity, with the
162 exception of knee extension at 120 °/s. These muscles have an important role and
163 may be associated with jumping, changing direction while running and kicking as
164 well as movements where success is partially related to velocity [12].

165 The results demonstrate that the U17 group is able to maintain a required velocity
166 for longer durations (larger LR), and therefore, it was expected that this group had
167 also a lower TTVA because these outcomes are inter-related [5, 8, 19]. Le Gall *et al.*
168 [23] stated that the quadriceps femoris presents maximum development at the age of
169 21 years while thereafter, performance seems to remain stable. Contrary to this, the
170 hamstrings achieve their maximum improvement at the age of 16 years [25]. Thus,
171 the fact that the majority of subjects in the U17 group had already reached this age
172 (16 years) may explain the results for the flexors, because there was any difference
173 between groups. For the results found for the extensors, the TVA_{3D} surface map
174 provides valuable information and a more detailed biomechanical analysis, because,

175 although the U17 group shows better results for TTAV and LR, the PRO group
176 maintained higher torques in both movement directions in comparison to the U17.
177 That is, the muscle performance of the PRO group is more efficient than the U17
178 group. This conclusion can only be taken when analyzing the TVA_{3D} surface maps,
179 hence it allowed for a broader view of the isokinetic assessment [17, 19, 23].

180 This study has some limitations, such as the maturational status of athletes and
181 skill levels. It is suggested that in future studies the athletes should be separated into
182 groups according to both characteristics. In addition, it is known that isokinetic
183 evaluations (which are the gold standard for muscle performance) are not always
184 available in practice. Several studies have related isokinetic results with field tests
185 [11, 27, 28], though none correlated the outcomes in this study with such tests, so
186 further studies with these objectives are needed. Furthermore, the recommended
187 rest periods between strength training could not be done due to logistical issues of
188 the team. This may have biased the results. Finally, data presented here is
189 representative of just one soccer team so caution should be exercised when
190 extrapolating to other populations.

191

192 **CONCLUSIONS**

193

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

199

200 **Practical Implications**

201

202 - The evaluation of outcomes such as TTAV and LR can provide information on muscle
203 efficiency of athletes and serve as a support for strength training prescriptions.

204 - Surface maps improve understanding of muscle behavior and allow for a
205 complementary analysis that can support strength training prescriptions.

206

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