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Physical and physiological attributes of soccer goalkeepers - Should we rely only on means and standard deviations?

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ABSTRACT

Nikolaidis, P., Ziv, G., Arnon, M., & Lidor, L. (2015). Physical and physiological attributes of soccer goalkeepers - Should we rely only on means and standard deviations? *J. Hum. Sport Exerc., 10*(2), pp.602-614. The purpose of this study was twofold: (a) to profile physical characteristics and physiological attributes of soccer goalkeepers (GKs) who were divided into three age groups – under 16 years, 16-19, and over 19, and (b) to examine the intra-individual variability among the GKs in each age group on all physical and physiological measurements performed in the study. The GKs underwent a series of physical (e.g., height, body mass, and percentage of body fat) and physiological (e.g., anaerobic profile, power and strength, and flexibility) tests. The three main findings of the current study were: (a) differences in physical characteristics and physiological attributes existed between GKs in the three age groups, (b) intra-individual variability can be found in most physical characteristics and physiological attributes of the GKs, and (c) the intra-individual variability was observed in all three groups. These findings emphasize the need for coaches to examine the intra-individual variability in GKs on their teams. These findings can be used by coaches when planning specific training programs for GKs of different age and skill levels. **Key words**: SOCCER, EXERCISE TEST, GOALKEEPER, ATHLETIC PERFORMANCE.

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INTRODUCTION

In a recent review of studies (N = 23) examining physical characteristics and physiological attributes of goalkeepers (GKs) in soccer (Ziv & Lidor, 2011), a number of observations were made, among them: (a) professional adult GKs are usually over 180 cm tall and have a body mass of over 77 kg; (b) studies on agility and speed produced mixed results, with some showing similar values between GKs and field players and others showing reduced performance in GKs; (c) GKs usually have higher vertical jump (VJ) values when compared to players playing the various field positions.

In the abovementioned review, as well as in other studies examining physical characteristics and physiological attributes of GKs (e.g., Hencken & White, 2006; Sutton et al., 2009), only means and standard deviations were provided. The intra-individual variability among the GKs was not discussed. Indeed, means and standard deviations are the most common statistical values used when attempting to profile physical and physiological characteristics of athletes.

Only a small number of studies discussed the issue of intra-individual variability among elite performers in sport. For example, in a recent study on female volleyball players (Nikolaidis et al., 2012), it was observed that large individual variability existed in most of the physical characteristics (e.g., body mass and height) and physiological attributes (e.g., aerobic capacity and anaerobic power) measured among the players, as well as that the intra-individual variability was observed in all age groups classified in this study (under 14, 14-18, and over 18 years of age). Intra-individual variability was also discussed in studies on elite pistol shooting performers (Ball et al., 2003) and elite golfers (Hassmen et al., 2004).

In order to develop better training programs that reflect the specific needs of the individual GK, it may also be important to examine the intra-individual variability that exists among them. This information can be used effectively by soccer coaches, GKs coaches, and strength and conditioning coaches to enable the individual GK to most benefit from the training program. In soccer, it has been already argued that various factors can predispose players to be successful, and that heterogeneity exists in the anthropometric characteristics and physiological attributes of players in top soccer teams (Reilly et al., 2000). This assumption could be true for GKs as well.

Therefore, the purpose of this study was twofold: (a) to profile physical characteristics and physiological attributes of three age groups of GKs - under 16 years, 16-19, and over 19, and (b) to examine the intra-individual variability among the GKs in each age group in all physical and physiological measurements performed in the study. We mainly focused in the current study on the measurement and assessment of power and strength attributes in GKs, since these attributes were measured and assessed in only a few studies. For example, in a review of studies on soccer GKs (Ziv & Lidor, 2011), only four studies examining power and strength values in adult GKs were found. In addition, only one study examined power value (VJ only) in adolescent GKs. The relatively scarce literature on this topic warrants examination of these values in GKs.

MATERIAL AND METHODS

Participants

Sixty-six male GKs participated in the current study. They were divided into three age groups: (a) age 16 and under (n=31, 14.2±1.2 years), (b) between the ages of 16 and 19 (n=11, 17.0±.7 years), and (c) over the age of 19 (n=31, 24.3±4.4 years). The adolescent GKs, namely all the GKs who were under the age of

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19, were members of B, C, D, and E series clubs (2nd, 3rd, 4th, and 5th best leagues for soccer, respectively) in Greece, and competed in non-classified tournaments, since no national tournaments were held for these age groups. The adult players – those who were above the age of 19 – were highly skilled and were members of B, C, D, and E series clubs participating in national tournaments. The rationale for the classification of the three groups in our study was that national and international soccer competitive leagues and tournaments are typically organized according to these age groups.

The GKs had soccer experience of 5.3±2.2 years for the under-16 group, 4.9±2.5 years for the 16-19 group, and 11.8±6.0 years for the over-19 group. Total weekly training time was 380.0±128.4 min·wk-1 for the under-16 group, 325.8±102.6 min·wk-1 for the 16-19 group, and 442.5±203.3 min·wk-1 for the over-19 group. All GKs completed an informed consent form prior to participation. The parents of the players who were under the age of 18 approved the participation of their children in the study. In addition, the study was approved by an Institutional Review Board.

Procedures

Upon arrival at the Exercise Physiology Laboratory, participants were provided with a verbal explanation of the experimental design of the study. All testing was conducted by an experienced exercise physiologist (with experience in applied and research projects in exercise physiology). Testing took place during the competitive phase of the 2008-9, 2009-10, and 2010-11 seasons, on weekdays between 8:00 a.m. and 2:00 p.m. The testing order was similar in all groups: the physical characteristics were measured first, followed by the physiological attribute measurements. Testing lasted about 90 minutes for each GK. To prevent dehydration, ad libitum drinking was permitted for the GKs after the completion of the jumping tests. All participants were given a standardized warm-up, which included 10 minutes of cycling of moderate intensity and five minutes of stretching.

Testing. Devices and protocols. A series of physical and physiological tests were administered to the three groups of GKs. Testing devices and protocols are presented separately for the physical characteristics and the physiological attributes of the GKs, according to the testing order.

Physical characteristics. Height and body mass were measured using a stadiometer (SECA, Leicester, UK) and an electronic scale (HD-351, Tanita, Illinois, USA), respectively. Percent of body fat was calculated from the sum of 10 skinfolds using a skinfold caliper (Harpenden, West Sussex, UK). Calculations were based on the formula proposed by Parizkova (1978). Three trials were given for each anthropometric measurement in rotational order, and the average value was recorded.

Physiological attributes. The participants underwent seven tests, as follows:

(a) A sit-and-reach test for measuring flexibility - Participants completed the test twice, and the better score was recorded. A 15-cm advantage was given to the participants, namely that reaching the toes resulted in a score of 15 cm, reaching five cm further than the toes resulted in a score of 20 cm, and reaching five cm before the toes resulted in a score of 10 cm. The 15-cm advantage was provided in order to assess performances of those who could not reach their toes. This test was found to have high test-retest reliability [intra-class correlation coefficient (ICC) > .98)] (Gabbe et al., 2004).
(b) A PWC170 test for predicting maximal work capacity – Power work capacity at a heart rate (HR) of 170 beats per minute (PWC170) was employed as a measure of cardiorespiratory power (Astrand et al., 2003). Participants were asked to cycle on a cycle ergometer (Monark Ergomedics 828, Monark, Sweden) for two three-minute sessions against an incremental work

load. HR was recorded at the end of each session. The findings were plotted on a workload-HR graphical display, and PWC170 was calculated based on the linear relationships between the work load and HR. The test-retest reliability of this test was found to be moderate to high (r= .76) (Borg & Dahlstrom, 1962).

(c) A VJ test for measuring explosive power of the legs - Participants completed two counter-movement jumps (CMJ), with arm swing allowed using the photoelectric cells system Optojump (Microgate, Bolzano, Italy). The higher jump was recorded. Various VJ protocols were found to be highly reliable (r > .97) (Aragón-Vargas, 2000).

(d) An isometric handgrip strength test - Participants were asked to sit with the elbow of their testing arm resting on a table and bent at approximately 90˚. They were then instructed to squeeze the handle of a handgrip dynamometer (Takei, Tokyo, Japan) as hard as possible for five seconds. Two trials were performed for each hand, with a one-minute rest between the trials. The better of the trials was recorded as the maximal effort for each hand (Skinner, 2005). In one study, the test-retest reliability of this test was found to be high (ICC = .98) (Essendrop et al., 2001).

(e) Isometric back and leg strength tests - Two tests were performed. In the first one (combined back-and-leg test), the chain length on the dynamometer was adjusted so that the participants squatted over the dynamometer with their knees flexed at approximately 30˚. In the second test (back strength test), their legs were straight and the back was flexed to allow the bar to be at the level of the patella (Skinner, 2005). A back dynamometer (Takei, Tokyo, Japan) was used in the two tests. In one study, isometric back flexion and extension test was found to be reliable (ICC = .93-.97) (Essendrop et al., 2001).

(f) A force-velocity (F-v) test was performed for the legs on a cycle ergometer (Monark Ergomedics 874, Monark, Sweden). This test employed various applied braking forces that elicit different pedaling velocities in order to derive maximal power (Heller, 2005). The GKs performed five supramaximal pedal sprints, each lasting seven seconds, against incremental braking force. The test began with a braking force of 29.4 N. In every subsequent sprint, 9.8 N was added. The recovery period between each exercise bout was five minutes. During each sprint, participants were encouraged to reach their maximal velocity as quickly as possible. The value of peak velocity was recorded in each sprint and used to estimate F-v parameters. Based on the inverse linear F-v relationship, theoretical maximal values of force (F0) and velocity (v0) were calculated and maximal power (Pmax) was calculated from the equation:
$P_{max} = 0.25 \cdot F0 \cdot v0$.

(g) The Wingate Anaerobic Test (WAnT) - From a stopped position, participants were asked to pedal as hard as they could for 30 seconds on a cycle ergometer (Monark Ergomedics 874, Monark, Sweden), with a resistance equal to 7.5% of their body mass. This test of anaerobic power was found to be both valid and reliable (Inbar et al., 1996).

Statistical Analyses

Descriptive statistics are presented as means ± SD, and an Alpha level of .05 was set for all statistical tests. A one-way analysis of variance (ANOVA) was used to examine differences between the three age groups on all the physical and physiological tests. When statistically significant differences were found, a Tukey's HSD post-hoc procedure was performed. Levene's test of homogeneity of variance was used to assess whether variance differed between the groups. Z-scores for two players from each age group were calculated based on both physical and physiological tests. The Z-scores were calculated for each individual test and for four categories: (a) physical characteristics, (b) power, (c) strength, and (d) flexibility. The

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reliability of these categories was assessed using Cronbach's Alpha. The two players who were selected from each age group exhibited similar Z-scores.

RESULTS

Intra-individual Variability

The Levene test indicated that no statistically significant differences in variance were found between the age groups in most physical and physiological measurements. Significant differences in the homogeneity of variance were found only in height, fat free mass (FFM), and absolute mean power in the WAnT. The intra-individual variability in a box-plot style for the physical characteristics of the GKs is presented in Figure 1. The intra-individual variability for the power achievements and the strength and flexibility achievements are presented in Figures 2 and 3, respectively. The box plots represent the 25th quartile, the median, and the 75th quartile of the measured variables. As can be seen in Figures 1 to 3, a large individual variability exists in most of the variables in all age groups. In some cases (e.g., height, body mass), it appears that individual variability decreases as age increases. One example of such variability that is supported by differences in homogeneity of variance between the three age groups is height.

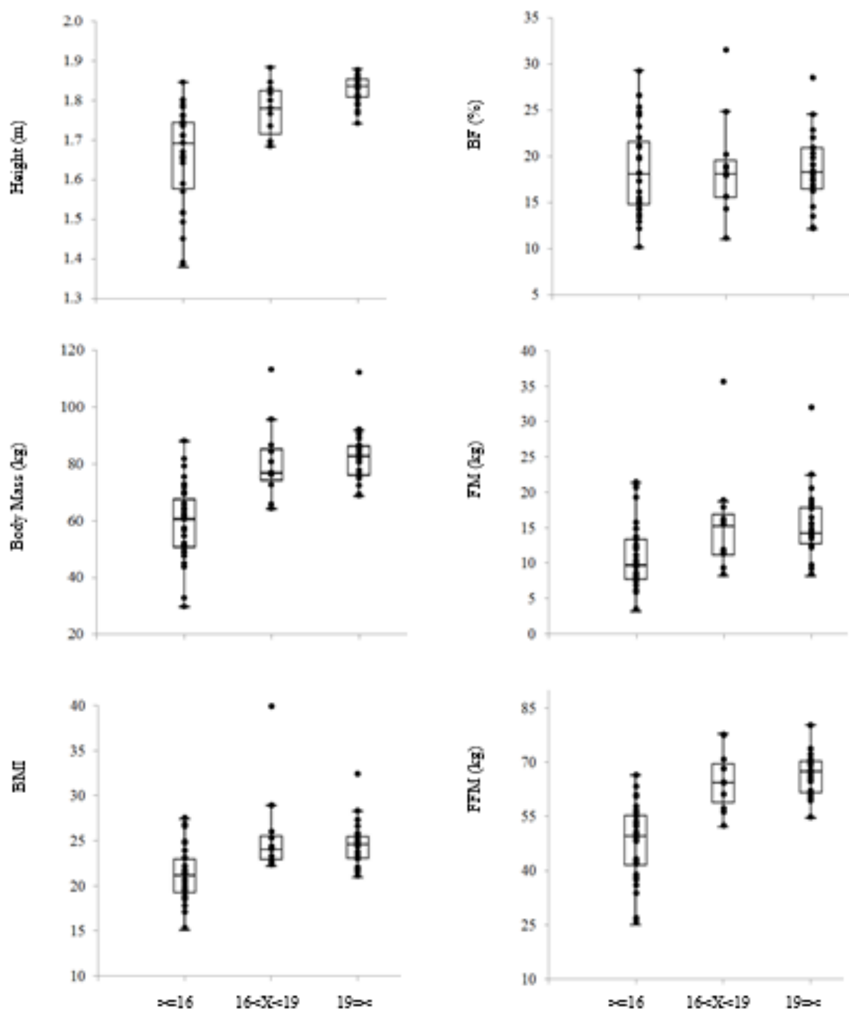

Figure 1. The intra-individual variability in a box-plot style for the physical characteristics of the GKs

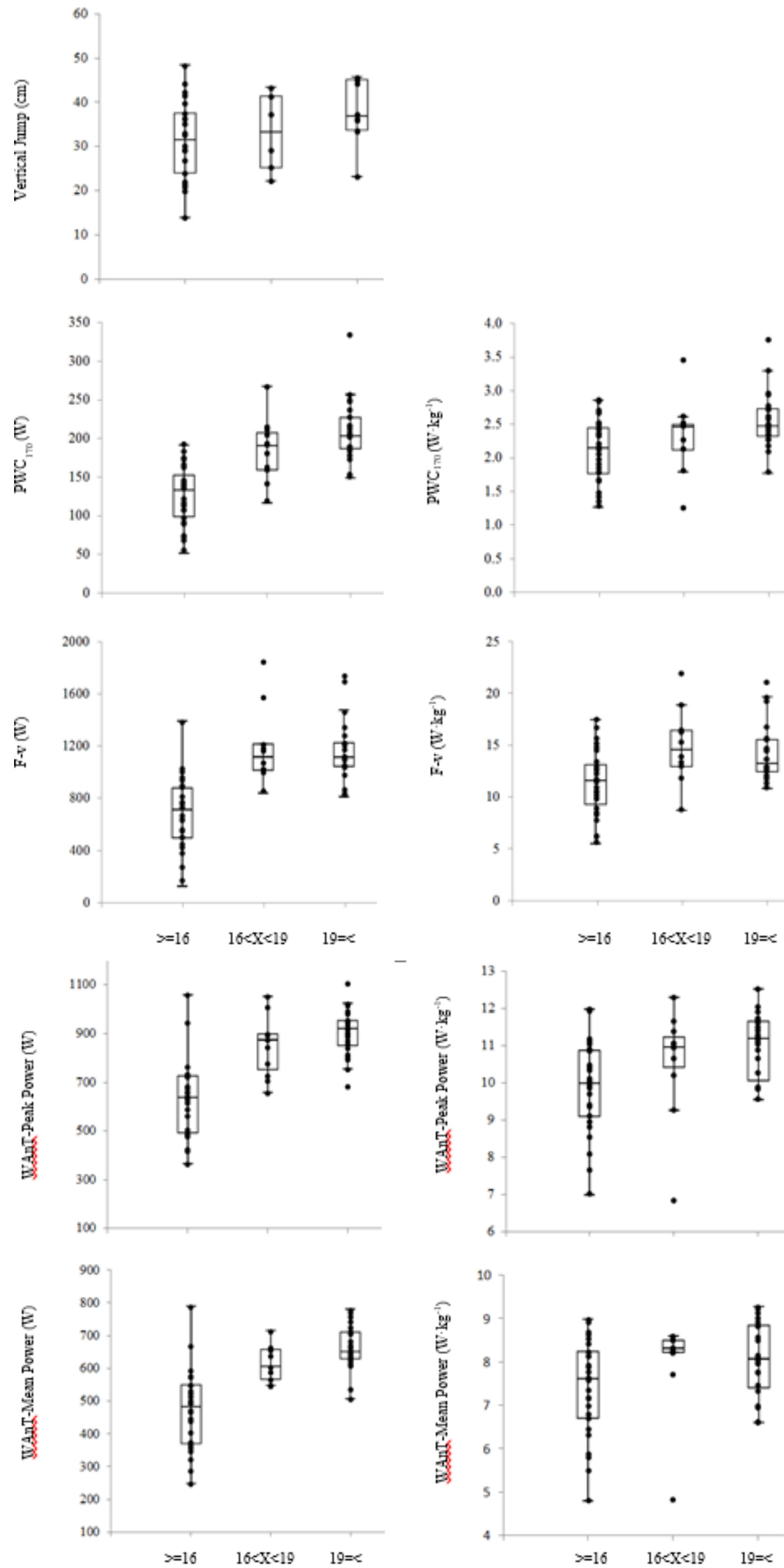

Figure 2. The intra-individual variability in a box-plot style for the power achievements of the GKs

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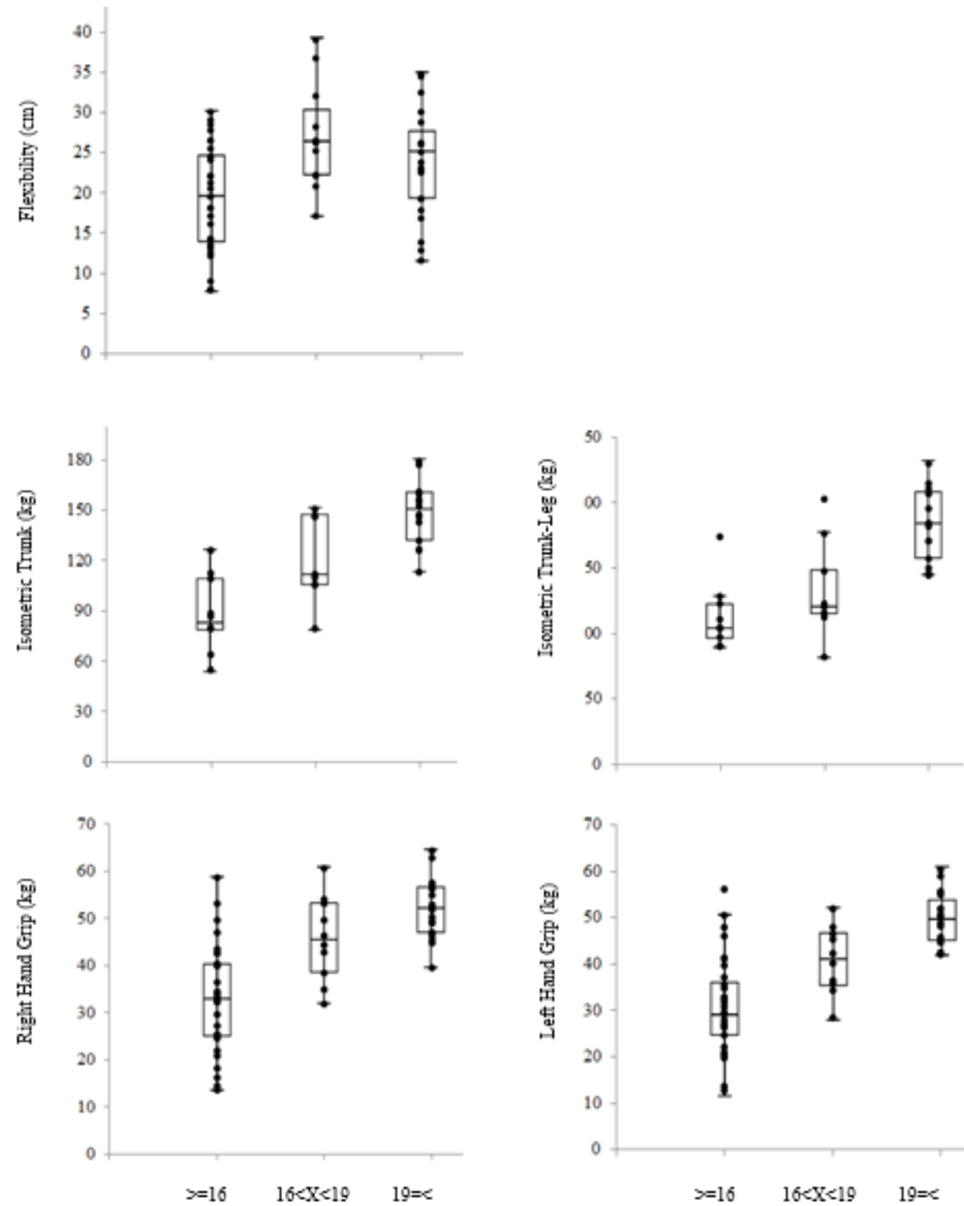

Figure 3. The intra-individual variability in a box-plot style for the strength and flexibility achievements of the GKs

Reliability values of the four testing categories (i.e., physical characteristics, power, strength, and flexibility) were adequate (Cronbach's alpha > .7). The overall Z-scores and the different Z-scores of two GKs from each age group are presented in Figure 4, Part A: The two GKs from each age group share a similar overall Z-score, but have different Z-scores for each of the four testing categories. For example, in the under-16 group, the two GKs have an overall Z-score close to zero. However, one has a Z-score of approximately .5 in the physical characteristics category while the other has a Z-score of approximately -.3 for the same category. Similarly, in the over-19 group, the two GKs have a similar overall Z-score of approximately .5, but one has a flexibility score of approximately 1.5 while the Z-score of the other GK for the same category is approximately -1.0.

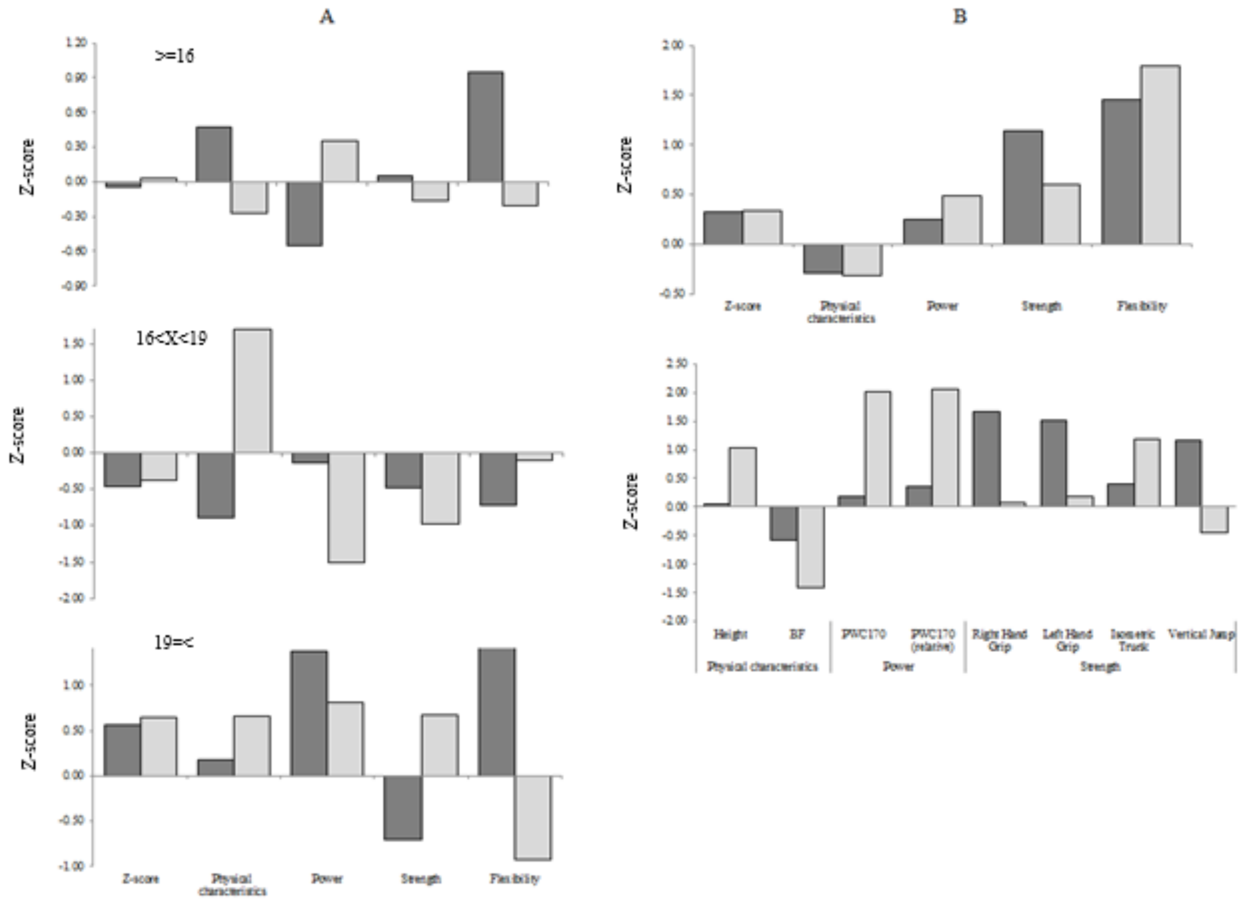

Figure 4. The overall Z-scores and the different Z-scores of two GKs from each age group (Part A) and the intra-individual variability within each category (Part B)

The intra-individual variability within each category is shown in Figure 4, Part B. The values of the two GKs presented in Part B suggest that both have similar overall Z-scores and similar category-based Z-scores. However, the similar category-based Z-scores are based on different Z-scores from the individual tests that make up each category. For example, while both GKs have similar Z-scores for their physical characteristics, there are differences of approximately one standard deviation between them in %BF and height.

Physical and Physiological Testing

The physical characteristics, power, strength, and flexibility data of the three age groups are presented in Table 1.

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Table 1. Means, standard deviations, and significance values of the physical characteristics, power tests, strength, and flexibility of the under-16, 16-19, and over-19 groups

Age group	Under 16 (*n* = 31)	16 to 19 (*n* = 11)	Over 19 (*n* = 24)	Significance	η^2
Physical Characteristics					
Height (cm)*	166.1±12.5	177.6±6.7	182.6±3.5	$F_{(2, 63)} = 22.5$, $p<.001$	.42
Body mass (Kg)*	59.6±13.4	81.2±13.9	82.5±9.4	$F_{(2, 63)} = 28.2$, $p<.001$	.47
BMI*	21.4±2.9	25.8±5.0	24.7±2.5	$F_{(2, 63)} = 11.4$, $p<.001$	.27
BF (%)	18.6±4.9	18.8±5.5	18.6±3.8	$F_{(2, 63)} = .006$, N.S.	.00
FFM (kg)*	48.3±10.2	65.4±8.3	66.9±5.6	$F_{(2, 63)} = 38.3$, $p<.001$	.55
FM (kg)#	11.3±4.6	15.7±7.5	15.6±4.9	$F_{(2, 47)} = 5.5$, $p = .006$	.15
Power					
PWC_{170} test					
Absolute power (W)*	125.7±37.8	184.4±40.2	208.5±39.5	$F_{(2, 57)} = 28.9$, $p<.001$	.50
Relative power ($W \cdot kg^{-1}$)#	2.1±.5	2.3±.5	2.5±.4	$F_{(2, 57)} = 5.7$, $p=.005$	.17
WAnT					
Peak power (W)*	629.9±157.2	847.1±122.8	904.0±93.2	$F_{(2, 58)} = 30.1$, $p<.001$	.51
Relative peak power ($W \cdot kg^{-1}$)#	9.9±1.2	10.6±1.5	11.0±.8	$F_{(2, 58)} = 5.7$, $p=.006$	.16
Mean power (W)*	470.1±121.4	612.6±57.7	659.4±66.6	$F_{(2, 56)} = 26.3$, $p<.001$	.49
Relative mean power ($W \cdot kg^{-1}$)	7.4±1.1	7.9±1.2	8.0±.8	$F_{(2, 56)} = 2.6$, N.S.	.09
Fatigue index (%)	47.1±6.5	46.7±10.5	48.4±6.9	$F_{(2, 56)} =.3$, N.S.	.01
Force-velocity test					
Absolute power (W)*	702.0±260.8	1190.6±298.3	1165.8±235.0	$F_{(2, 56)} = 24.5$, $p<.001$	.47
Relative power ($W \cdot kg^{-1}$)*	11.4±3.2	14.9±3.7	14.2±2.8	$F_{(2, 56)} = 7.3$, $p=.002$	.21
Vertical jump (cm)	31.3±8.9	32.8±8.7	37.7±7.2	$F_{(2, 35)} = 2.0$, N.S.	.10
Strength and flexibility					
Right-hand grip (kg)*	33.2±11.1	45.6±9.0	51.9±6.2	$F_{(2, 58)} = 25.0$, $p<.001$	.46
Left-hand strength (kg)&	31.1±10.3	40.8±7.2	49.6±5.5	$F_{(2, 58)} = 28.8$, $p<.001$	.50
Isometric trunk (kg)&	88.3±22.1	122.7±25.7	148.5±19.0	$F_{(2, 30)} = 22.1$, $p<.001$	.60
Isometric trunk-legs (kg)$	112.2±24.9	132.4±36.7	181.4±27.2	$F_{(2, 30)} = 17.7$, $p<.001$	.54
Modified sit and reach (cm)*	19.4±6.5	26.9±6.8	24.1±6.8	$F_{(2, 62)} = 6.5$, $p = .003$	.17

N.S. = Not Significant.
* = Under-16 group significantly different from the other groups.
# = Under-16 group significantly different from the over-19 group.
& = Significant differences between all groups.
$ = Over-19 group significantly different from the other groups.

Physical Characteristics

Height, body mass, BMI, and FFM were lower in the under-16 group when compared to the two other groups. FM was significantly different between the under-16 group and the over-19 group.Effect sizes were small to moderate, and ranged from .15 to .47. The difference in FM between the under-16 group and the

16-19 group was just outside the limit for statistical significance (p = .052). No significant differences were found between groups in %BF.

Power
Absolute power values were lower in the under-16 group when compared to the two other groups in the PWC170 test, the WAnT, and the force-velocity test, with moderate effect sizes ranging from .47 to .51. These differences were significant even when data were presented relative to body mass, although effect sizes were much lower and ranged from .09 to .21. No significant differences between groups were found in the VJ values.

Strength and Flexibility
Significant differences were found in all tests between at least two groups, with moderate effect sizes ranging from .46 to .60. The only exception was the low effect size in the flexibility test (.17).

DISCUSSION

The main finding of this study was that intra-individual variability exists in most physical and physiological tests in the three different age groups of GKs. In addition, players who had similar overall Z-scores attained these scores by different individual Z-scores in the physical and physiological tests. Lastly, differences in physical characteristics and power and strength attributes were observed between all three age groups.

Intra-individual Variability
The intra-individual variability of the GKs as observed in our study is presented in Figures 1-3. Figure 4, Part A contributes additional information on the intra-individual variability phenomenon by showing that even when two players appear similar because they have similar overall Z-scores, these Z-scores are based on different Z-scores of their physical characteristics, power values, strength values, and flexibility. Lastly, Figure 4, Part B, adds one more layer to the phenomenon of the intra-individual variability by presenting two players with similar overall Z-scores and category based Z-scores, but who have very different individual testing Z-scores.

A number of physical characteristics and physiological attributes can affect goalkeeping performance. In addition, different combinations of these characteristics and attributes can lead to different levels in achieving success. As Reilly et al. (2000) suggested, various factors predispose individuals towards a successful soccer career, and since heterogeneity exists in anthropometric and physiological values, it is impossible to accurately describe the specific individual requirements for success. For example, a tall GK with an average reaction time and an average VJ capability can block a shot on goal. However, this same shot can be blocked by a GK of average height, who possesses excellent VJ capability and a quick reaction time. Moreover, a third GK can have average physiological capabilities, but possesses superior visual anticipation capabilities that can help him or her perform similarly to the physiologically superior GKs. Therefore, the fact that intra-individual variability exists between high-achieving GKs is to be expected.

The presence of intra-individual variability emphasizes the need to adopt a more individualized approach by soccer coaches and strength and conditioning coaches when working with GKs in different age groups. Based on selected physiological tests, the strengths and weaknesses of each GK can be determined. Then, based on the results of these tests, coaches can decide to emphasize one or more aspects of the individual GK's training program. For example, a GK with lower than average VJ values can perform

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plyometric training to improve his or her VJ ability, while a GK who lacks flexibility can add flexibility drills to his or her training.

Despite the assumption that intra-individual variability will be reduced as GKs grow older (i.e., in the over-19 group), the findings of this study suggest that the variability is similar in adolescents and adults. These findings are in line with previous data on female volleyball players (Nikolaidis et al., 2012).

Physical Characteristics

The height (182.6±3.5 cm) and body mass (82.5±9.4 kg) of the over-19 group in this study is in line with data of previous studies: height and body mass of adult GKs were found to be over 180 cm and over 77 kg, respectively (Ziv & Lidor, 2011). In the 16-19 group, height (177.6±6.7 cm) was similar to that found in two previous studies (Gil et al., 2007; Tahara et al., 2006), although body mass (81.2±13.9 kg) was higher by approximately 7-10 kg when compared to the findings of those studies. In the under-16 group, height (166.1±12.5 cm) was slightly lower than that reported in a group of under-14 GKs in Hong Kong (169.0±6.0 cm), and body mass (59.6±13.4 kg) was higher than that reported in that group (54.6 ± 7.3 kg) (Wong et al., 2009).

Percent body fat in the over-19 group in this study (18.6%) is at the high end of the range of values found in other studies of adult GKs. Such values ranged from as low as 10.3% in GKs from a League 1 club in France (Carling & Orhant, 2010) to 20.2% in GKs from the first league in Croatia (Matkovic et al., 2003). Percent body fat of the adolescents in our study (18.6 and 18.8% for the under-16 and the 16-19 group, respectively) was higher than those found in two previous studies: 12.2% for GKs with a mean age of 17.3 years (Gil et al., 2007), and 13.7% for GKs with an average age of 16.8 years (Tahara et al., 2006).

Power and Strength

In a review of physical characteristics and physiological attribute of GKs, only four studies providing data on power and strength in GKs were found (Ziv & Lidor, 2011). Comparisons of the data from our study can be made with those of only two studies. For the over-19 group, the relative peak power in the WAnT (11.0 W·kg-1) is lower than that reported for 13 English GKs from eight clubs of the 1st and 2nd divisions (14.8±1.9 W·kg-1) (Davis, Brewer & Atkin, 1992). This difference can be partly explained by the higher level of GKs in the leagues in England. For the under-16 group, the VJ values obtained in our study (31.3±8.9 cm) were much lower than those reported for 10 under-14 year-old GKs from Hong Kong (52.5±5.7 cm) (Wong et al., 2009). It is difficult to explain the differences between the results of the two studies. However, factors such as the GKs' experience, the GKs' level of expertise, the testing apparatus, the timing of measurement, and the GKs' motivation may have contributed to such differences.

Although variables such as agility and reaction time are assumed to be more relevant to GKs, superior power and strength capabilities can prove useful for a successful GK performing various defensive tasks in soccer - diving, blocking, catching, and deflecting. A recent analysis of GKs' defense activities from the 2002 World Cup reported that GKs performed 6.2±2.7 dives per game, 3.8±2.3 jumps per game, and 18.7±6.0 displacements (forward, sideways, and backwards) per game (De Baranda et al., 2008). It is assumed that developing above-average power can help the GK improve his or her abilities to perform needed displacements faster and help him or her block, catch, or deflect difficult shots on goal.

Practical Applications

It is concluded in our observational study that GKs' individual data should be used by coaches when planning specific training programs for GKs. Individual data can help coaches to better assess the physical-physiological profile of the GK, and in turn to select the most appropriate activities/drills for each of the GKs on the team. The better the match between the training program and the needs/preferences of the individual GK, the higher the chances that the GK will benefit from the specific training program.

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