SJSR SWEDISH JOURNAL OF SCIENTIFIC RESEARCH

ISSUE 01 JUNE
VOLUME 6 - 2019

ISSN
2001-9211

The Swedish Journal of Sientific Research (SJSR)
ISSN 2001-9211. Volume 6. Issue 1 June 2019

The Swedish Journal of Scientific Research

Original Article

$\dot{V}O_2$ decrease Before Exhaustion During Constant Load Exercise. Role of Respiratory Muscles

Abderraouf Ben Abderrahman[1]*, Lotfi Bouguerra[1], Fatma Rhibi[2], Armel Cretual[2], Mohamed Ansari[4], Amel Chebbi[3], Jacques Prioux[2]

[1]Higher Institute of Sport and Physical Education of Ksar-Said, Tunisia, [2]Movement, Sport, and Health Sciences Laboratory, University of Rennes 2, Rennes, France, [3]Faculty of Medicine of Tunis, Tunisia, [4]Dubaï Sports Council, United Arab Emirates

ABSTRACT

Objectives: The aim of our work was to analyse the $\dot{V}O_2$ kinetic during a constant load exercise, to check the existence of a $\dot{V}O_2$ decrease at the end of this kind of exercise and finally to study the respiratory muscles strength evolution, before and after this kind of exercise. **Patients and Methods:** Eight endurance trained athletes (20.6 ± 2.7 yrs) performed three field-tests until exhaustion: firstly a maximal graded test to determine their maximal oxygen uptake ($\dot{V}O_{2max}$) and maximal aerobic velocity (MAV) and secondly two constant velocity exercises on track at 100% (t_{lim100}) and 95% of MAV (t_{lim95}) until exhaustion. **Results:** Our study outcomes revealed a $\dot{V}O_2$ decrease before the end of exercise for three subjects. The mean decrease duration was 51.3 ± 13.4 s and represented 8.3 ± 2.1 % of the total exercise duration. Maximal inspiratory and expiratory pressures (PI_{max} and PE_{max}), measured before and after exercise were considered as respiratory muscle strength indices and were not significantly different before or after the exercise. **Conclusion:** The existence of a $\dot{V}O_2$ decrease before the end of the exercise, already highlighted in the literature is confirmed. Our results indicated that respiratory muscle fatigue was not explicative for $\dot{V}O_2$ decrease. However, further studies are necessary to confirm these results.

Keywords: Continuous exercises, $\dot{V}O_2$ decrease, respiratory muscle strength, maximal respiratory pressures

BACKGROUND

During exercise, muscle and pulmonary $\dot{V}O_2$ uptake ($\dot{V}O_2$) increase approximately exponentially to a steady state until the end of exercise [1]. However, Perrey et al. [2] during a continuous exercise realized on treadmill at 95% of v$\dot{V}O_{2max}$ (velocity associated with $\dot{V}O_{2max}$), observed a $\dot{V}O_2$ decrease before exhaustion for 7 of their 13 subjects (54 %). This $\dot{V}O_2$ decrease before exhaustion had been also found by Astrand and Saltin [3], Nummela and Rusko [4] and Heubert et al. [5] during a maximal constant load exercise. Nevertheless, this decrease is merely limited to an observation in these studies. More recently, Thevenet et al. [6] during intermittent exercise (105% of maximal aerobic velocity (MAV) alternated with passive recovery) with trained adolescents, also showed a $\dot{V}O_2$ decrease before exhaustion. According to these authors, this result could be explained by a minute ventilation ($\dot{V}_E$) decrease. In their study, Perrey et al. [2] also suggested that ventilatory system deterioration could explain $\dot{V}O_2$ decrease before exhaustion. Unfortunately, these authors did not highlight specific characteristics for subjects with a $\dot{V}O_2$ decrease. Considering respiratory muscles fatigue as a condition in which there is a loss in the capacity for developing force of muscle, which is reversible by rest [7], we hypothesized that the respiratory muscle strength loss could be the origin of

Access this article online

Website: http://sjsr.se/

ISSN: 2001-9211

Address for correspondence:
Abderraouf Ben Abderrahman, Higher Institute of Sport and Physical Education of Ksar-Said, Tunisia.
Tel: (00 216) 20 316 494, E-mail: benabderrahmanabderraouf@yahoo.fr

$\dot{V}O_2$ decrease during continuous exercise. Maximal respiratory pressures are considered a good index of respiratory muscle strength [8]. Moreover, at the end of the exercise, respiratory frequency (fr) increase could be insufficient compared to tidal volume (V_T) decrease and hence, according to the relationship $\dot{V}_E = V_T \times fr$, could be responsible for $\dot{V}_E$ decrease [9].

OBJECTIVES

Then, the aim of our work was to analyse the $\dot{V}O_2$ kinetic during a constant load exercise, to check the existence of a $\dot{V}O_2$ decrease at the end of this kind of exercise and finally to study the respiratory muscles strength evolution, before and after this kind of exercise.

PATIENTS AND METHODS

Subjects

Eight male physical education students (mean age 20.6 ± 2.7 yrs) volunteered to participate in this study. All were from the same athletic club and regularly practised athletics for at least 3 years. Subjects were 19 to 27 years old. Their mean ± SD for mass, height and percentage of fat were 70.5 ± 3.1 kg, 180.2 ± 6.2 cm and 12.4 ± 2.2 %, respectively. Before testing, the subjects underwent a medical examination and were fully informed of the experimental procedures and a signed consent was obtained from the subjects. The inclusion criteria required for subjects was the absence of cardiovascular diseases; pre- or diabetes risk and hypertension (i.e., blood pressure > 140/90 mmHg) and absence of electrocardiogram abnormalities. This study had been approved by the University of Nantes Research Ethics Committee.

Overview

Subjects performed three field-tests until exhaustion on a 400-m outdoor tartan track at the same time of the day, with at least 48h rest between each test [10]. Atmospheric conditions were checked before each test ensuring that all sessions were carried out under similar environmental conditions (wind speed lower than 2.5 $m.s^{-1}$; temperature between 18 and 23°C; humidity between 40 and 70%). Athletes first performed a maximal graded test to determine $\dot{V}O_{2max}$ and MAV. Then, they performed in a randomized order two continuous exercises until exhaustion at 100% (t_{lim100}) and 95% (t_{lim95}) of MAV. During all tests, we used the Cosmed K4b² breath-by-breath portable metabolic system (Cosmed K4b², Rome, Italy; [11]) in order to determine $\dot{V}_E$, V_T, fr and $\dot{V}O_2$. Further details about the system are provided elsewhere [12]. The K4b² was calibrated before the beginning of each test according to the manufacturer's guidelines. Heart rate (HR) was continuously monitored (Polar Electro, Kempele, Finland).

Maximal Static Mouth Pressure Measurements

Maximal respiratory pressures, considered as a good index of respiratory muscle strength, can be used in order to appreciate respiratory muscle fatigue [13]. Maximal inspiratory (PI_{max}) and expiratory (PE_{max}) pressures were respectively measured at residual volume (RV) and total pulmonary capacity (TPC) with a ZAN betterflow portable device (Flowhandy ZAN 100, Messgeraete Gmbh, Germany) using the technique of Black and Hyatt [14]. This measure was realized in the athletics stadium, just next to the athletics tracks, by the same experimenter at rest and 3 min after the end of the test. In each case, PI_{max} and PE_{max} were measured 5 times respectively. The highest and lowest values were rejected and the three others were averaged for data processing [15]. Maximal pressures were generated at the mouth as previously detailed [16].

Maximal Graded Test

Red cones were set at 20 m intervals along the track (inside the first line). The initial speed of the maximal graded test was 8 $km.h^{-1}$ and was increased by 1 $km.h^{-1}$ every 2 min [17], to determine $\dot{V}O_{2max}$, MAV, peak minute ventilation ($\dot{V}_{E\ max}$) and peak respiratory frequency (fr_{max}). $\dot{V}_{E\ max}$ and fr_{max} were determined at the corresponding time associated with $\dot{V}O_{2max}$. The determination methods of MAV and $\dot{V}O_{2max}$ have been extensively described elsewhere [6].

Constant Load Exercises and Breathing Pattern Measurement

Athletes performed two constant load exercises until exhaustion (t_{lim}): a 100% of MAV constant exercise (t_{lim100}) to confirm the MAV values and a constant load exercise at 95% of MAV (t_{lim95}) to study $\dot{V}O_2$ decrease and its link with maximal respiratory pressures. For t_{lim95}, $\dot{V}_E$, V_T and fr values were averaged over a 2s period. Then, the values were averaged over 20 periods, each corresponding to 5% of the individual t_{lim} duration. The time course of $\dot{V}_E$, V_T, fr are presented on figure 1 for a representative subject. We also calculated the last minute $\dot{V}_E$ and fr values for t_{lim95}.

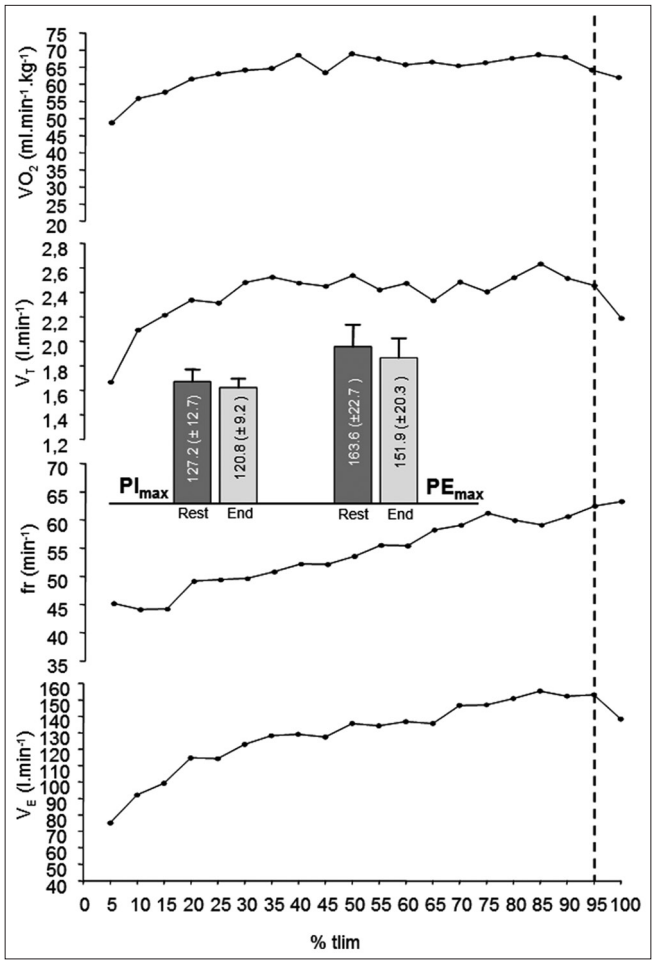


Figure 1: $\dot{V}O_2$, breathing pattern and maximal respiratory pressures for t_{lim95} in subject S2
$\dot{V}O_2$ **:** Oxygen uptake, V_T: tidal volume, fr: respiratory frequency, $\dot{V}_E$: minute ventilation; PI_{max} and PE_{max}: Maximal inspiratory and expiratory pressures. The vertical line shows the $\dot{V}_E$ decrease begining (95% t_{lim})

$\dot{V}O_2$ Kinetic Modelling

Exercise data before recovery were analysed using Matlab® (Mathworks, Natick, MA). The cardio-respiratory values were averaged on a 2 s periods and then smoothed thanks to a gaussian sliding mean processing along a 10 s wide window. The second order model also usually called a mono-exponential function that best fits the $\dot{V}O_2$ kinetic curve obtained was identified. Finally, a Kalman filter and a algorithm of abrupt changes detection [18] were used in order to detect a local loss of adequacy between the model estimated and the measured $\dot{V}O_2$ kinetic. If such a change was detected at the end of $\dot{V}O_2$ kinetics, the algorithm computed the best linear approximation of this phase ($\dot{V}O_2$ slope), meaning the part of the curve after the change. Based on $\dot{V}O_2$ slope values, we calculated amplitude ($ml.min^{-1}.kg^{-1}$) and duration (s) values to characterize the $\dot{V}O_2$ decrease [2].

Speed Control

The tests were performed on an athletic track equipped with cones every 20 m. During both constant load exercise and maximal graded test, running speed was maintained constant thanks to an experimenter on bicycle that the subject followed. Firstly, the latter experimenter was provided with a mp3 device (located in a bag carried across his shoulder by the experimenter and connected to him by headphones) giving an imposed time signal every 20 m and took care of the subject position on a level with the aft wheel. Secondly, another experimenter also paid attention to the subject position and to lap time.

Statistical Analysis

Mean PI_{max} and PE_{max} values were compared using a paired t-test. A linear regression model was used to assess the relationship between PI_{max}, PE_{max} both measured at the end of t_{lim95} and the duration of t_{lim95}. Normal Gaussian distribution of the data was verified with the Kolmogorov-Smirnov test (with Lilliefor's correction). For all statistical analyses, the level of significance was set at $p<0.05$. Statistical analyses for $\dot{V}O_2$, V_T, $\dot{V}_E$ and fr were not provided since they are not consistent regarding the weak number of subjects. Effect sizes (ES) were evaluated from the Cohen's d. ES of ≤ 0.2, 0.21-0.60, 0.61-1.20, 1.21-2.0, ≥2.0 were respectively considered as trivial, small, moderate, large and very large [19].

RESULTS

Maximal Graded Test

Mean values for MAV, $\dot{V}O_{2max}$, R_{max}, HR_{max}, $\dot{V}_{E\ max}$ and fr_{max} were: 18.4 ± 0.6 $km.h^{-1}$, 58.1 ± 3.5 $ml.min^{-1}.kg^{-1}$, 1.2 ± 0.1, 192.1 ± 6.2 bpm, 151.8 ± 11.1 $l.min^{-1}$ and 55.1 ± 6.5 min^{-1} respectively (Table 1). In subjects with $\dot{V}O_2$ decrease, mean values of MAV (18.5 ± 0.9 $km.h^{-1}$), $\dot{V}O_{2max}$ (56.3 ± 4.3 $ml.min^{-1}.kg^{-1}$), R_{max} (1.2 ± 0.0), HR_{max} (190.7 ± 7.6 bpm), $\dot{V}_{E\ max}$ (148.4 ± 5.7 $l.min^{-1}$) and fr_{max} (57.9 ± 5.6 min^{-1}) did not present any particularly higher or lower values compared with mean values of MAV (18.4 ± 0.5 $km.h^{-1}$), $\dot{V}O_{2max}$ (59.2 ± 2.8 $ml.min^{-1}.kg^{-1}$), R_{max} (1.2 ± 0.1), HR_{max} (193.0 ± 5.9 bpm), $\dot{V}_{E\ max}$ (153.9 ± 13.6 $l.min^{-1}$) and fr_{max} (53.4 ± 7.0 min^{-1}) in subjects without $\dot{V}O_2$ decrease.

Constant Load Exercises

Mean values for t_{lim100} were 363.4 ± 56.8 s and ensured the subjects MAV values. Mean values of t_{lim95} was

564.7 ± 75.3 s. Table 2 shows last minute $\dot{V}_E$ and fr values during t_{lim95}. The higher last minute $\dot{V}_E$ (149.4 ± 10.3 l.min^{-1} vs 147.3 ± 12.4 l.min^{-1}) and fr (54.4 ± 79 min^{-1} vs 55.0 ± 6.9 min^{-1}) values were not systematically observed in subjects with $\dot{V}O_2$ decrease.

$\dot{V}O_2$ Decrease Characteristics

The model used did reveal a slope at the end of exercise for subjects 2, 3 and 5 during t_{lim95} (Table 3), illustrating a $\dot{V}O_2$ decrease for these subjects. The mean duration of the $\dot{V}O_2$ decrease (DD) was 51.3 ± 13.4s and corresponded in mean to 8.3 ± 2.1% of total exercise duration.

Respiratory Muscle Fatigue

$\dot{V}O_2$, $\dot{V}_E$, fr and V_T expressed relatively to time to exhaustion for t_{lim95} are shown in figure 1. Only representative subject S2 is represented in this figure. This figure also shows individual values of PI_{max} and PE_{max} measured before and at the end of the exercise.

Table 1: Maximal graded test parameters

Subjects	MAV (km.h^{-1})	VO_{2max} (ml.min^{-1}.kg-1)	R_{max}	HR_{max} (bpm)	V_{Emax} (l.min^{-1})	fr_{max} (min^{-1})
S2	19.0	61.1	1.2	196.0	145.1	61.1
S3	17.5	52.9	1.2	194.0	145.0	51.5
S5	19.0	54.8	1.2	182.0	155.0	61.3
Mean±SD (n=3)	18.5 0.9	56.3 4.3	1.2 0.0	190.7 7.6	148.4 5.7	57.9 5.6
S1	19.0	58.0	1.2	185.0	156.7	55.8
S4	18.5	63.3	1.2	196.0	141.7	45.6
S6	18.5	59.6	1.0	200.0	150.6	57.8
S7	17.5	59.6	1.3	195.0	144.5	46.5
S8	18.5	55.7	1.2	189.0	176.0	61.3
Mean±SD (n=5)	18.4 0.5	59.2 2.8	1.2 0.1	193 5.9	153.9 13.6	53.4 7.0
Mean±SD (n=8)	18.4 0.6	58.1 3.5	1.2 0.1	192.1 6.2	151.8 11.1	55.1 6.5
ES (Cohen's d)	0.17	0.83	0.00	0.37	0.50	0.69

MAV: maximal aerobic velocity; $\dot{V}O_{2max}$: maximal oxygen uptake; R_{max}: maximal respiratory exchange ratio; HR_{max}: maximal heart rate; $\dot{V}_{E\ max}$: maximal minute ventilation; fr_{max}: maximal respiratory frequency. ES: effect size (Cohen's d)

Table 2: Minute ventilation and respiratory frequency values during t_{lim95}

Subjects	t_{lim95} (s)	Last minute V_E (l.min^{-1})	$\%V_{Emax}$	fr (min^{-1})	$\%fr_{max}$
S2	510.0	151.3	104.3	61.5	100.7
S3	624.0	138.3	95.4	45.8	88.9
S5	742.0	158.6	102.3	55.9	91.2
Mean±SD (n=3)	625.3 116.0	149.4 10.3	100.7 4.7	54.4 7.9	93.6 6.3
S1	474.0	143.9	91.8	52.4	93.9
S4	586.0	127.7	90.1	44.3	97.1
S6	632.0	159.9	106.2	60.4	104.5
S7	648.0	154.9	107.2	57.7	124.1
S8	479.0	149.9	85.2	62.2	101.5
Mean±SD (n=5)	563.8 82.9	147.3 12.4	96.1 9.9	55.4 7.2	104.2 11.8
Mean±SD (n=8)	564.7 75.3	148.1 10.9	97.8 8.3	55.0 6.9	100.2 11.0
ES (Cohen's d)	0.82	0.19	0.55	0.14	0.96

$\dot{V}_E$: mean last minute ventilation expressed in l.min^{-1} and relatively to $\dot{V}_{E\ max}$ (determined during maximal graded test - % $\dot{V}_{E\ max}$); fr: mean last minute respiratory frequency expressed in min^{-1} and relatively to fr_{max} (determined during maximal graded test - % fr_{max}). ES: effect size (Cohen's d)

Table 3: $\dot{V}O_2$ decrease characteristics during t_{lim95} for subjects S2, S3 and S5

Subjects	t_{lim} (s)	TD (s)	DD (s)	%DD	Δ (ml.min^{-1}.kg^{-1})	%Δ
S2	510.0	474.0	36.0	7.1	2.7	5.6
S3	624.0	546.0	78.0	12.5	2.5	5.8
S5	742.0	702.0	40.0	5.4	5.6	12.8
Mean±SD (n=3)	625.3 67.0	574.0 67.3	51.3 13.4	8.3 2.1	3.6 1.0	8.1 2.4

t_{lim95}: time to exhaustion performed at 95% of MAV; TD: time delay of $\dot{V}O_2$ decrease beginning; DD: decrease duration; %DD: percentage of decrease duration t_{lim95}; Δ: decrease amplitude; %Δ: percentage of $\dot{V}O_2$ decrease amplitude relatively to the total $\dot{V}O_2$ amplitude A, considered as the difference between $\dot{V}O_2$ plateau and $\dot{V}O_2$ at rest (t=0)

The vertical line in the figure represents the onset of $\dot{V}_E$ decrease and is linked to the other parameters. Despite the lack of statistical analyse in the three subjects with a $\dot{V}O_2$ decrease, V_T and $\dot{V}_E$ seemed to decrease and fr seemed to increase at the end of t_{lim95}.

Mean values of maximal inspiratory and expiratory pressures values (PI_{max} and PE_{max}) measured at rest (rest) and at the end of the exercise (end) are shown in figure 2. Statistical results did not highlight any significant evolution of PI_{max} (d = 0.21) and PE_{max} (d = 0.20) values between the rest and the end of the exercise during t_{lim95}. No significant relationship was found between PI_{max} [=83.8 + (0.063 × t_{lim95}), r^2 = 0.05, p=0.587], PE_{max} [=-6.96 + (0.27 × t_{lim95}), r^2 = 0.19, p=0.27], both measured at the end of t_{lim95}, and the duration of t_{lim95}.

DISCUSSION

The aim of our work was to analyse the $\dot{V}O_2$ kinetic during a constant load exercise, to check the existence of a $\dot{V}O_2$ decrease at the end of this kind of exercise and finally to study the respiratory muscles strength evolution, before and after this kind of exercise. Our study outcomes reveal a $\dot{V}O_2$ decrease before the end of exercise for three subjects. From a methodological point of view, firstly, $\dot{V}O_2$ data were averaged on a two seconds period. Data were analysed with Matlab® software and a second order model was applied to $\dot{V}O_2$ kinetics. An ad-hoc filtering process, based on Kalman filter was then used in order to detect the changes of model relatively to $\dot{V}O_2$ kinetic. When, and only when, a series of changes was detected at the end of $\dot{V}O_2$ kinetic, the software applied a linear phase. This latter was only applied after a $\dot{V}O_2$ steady state detection. As the linear phase is based on several decreasing plots, we conclude that the decrease observed is not due to measurement artefacts. Secondly, the $\dot{V}O_2$ decrease observed in our three subjects also cannot be explained by running speed variations. Indeed, running speed was maintained constant for each intensity thanks to four controls. Therefore, according to these methodological considerations, we concluded that the $\dot{V}O_2$ decrease could be only explained by physiological process. Moreover, the proportion of subjects with a $\dot{V}O_2$ decrease (47%) are close to those reported by Perrey et al. [2].

Respiratory Muscle Fatigue

One hypothesis put forward in order to understand this decrease in $\dot{V}O_2$ before exhaustion during continuous exercise concerns respiratory muscle fatigue [2]. During short intermittent exercise (30s at 105% of MAV alternated with 30s passive recovery) we have shown [6] a $\dot{V}O_2$ decrease before exhaustion. We also suggested that this $\dot{V}O_2$ decrease was partly connected with respiratory muscle fatigue. Maximal respiratory pressures, considered as a good index of respiratory muscle strength, can be used in order to assess respiratory muscle fatigue [13]. However, according to Hayot et Matecki [20] maximal respiratory pressures used as a fatigue index should be coupled with other fatigue evaluation methods. Thus, in our study, two approaches were used to appreciate the respiratory muscle fatigue. The first was related to maximal respiratory pressures (PI_{max} and PE_{max}) measurements and the second one depended on the use of V_T, fr and $\dot{V}_E$ kinetics [9]. Maximal respiratory pressure measurement fell within the range described by Leech et al. [21] and Chen et al. [22], and our results (Figure 2) did not present a significant difference between these two parameters at rest (rest) and at the end of the exercise (end). Since the phenomenon of a decrease in $\dot{V}O_2$ was not present in more than half of the subjects, it seems logical that there was no systematic fatigue of the respiratory muscles in the total group. But that does not necessarily mean

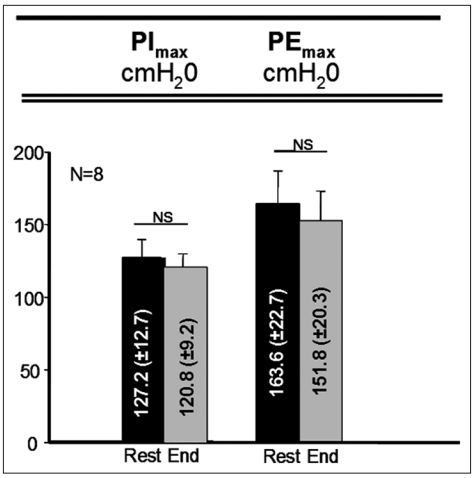


Figure 2: Mean values (± SD) for maximal inspiratory and expiratory pressures for the whole population during t_{lim95}
PI_{max} and PE_{max}: Maximal inspiratory and expiratory pressures.
NS : no significant difference

that respiratory muscles fatigue was not the cause of the decrease in $\dot{V}O_2$ in those three subjects. Moreover, PI_{max} and PE_{max} values seemed to be lower at the end of the exercise (Figure 2). We could hypothesize that even without a significant decrease, 95% of MAV intensity seems to induce respiratory muscle fatigue. Thevenet et al. [6] during intermittent exercise observed a longer decrease (30% of time to exhaustion) during a longer exercise duration (around 35min). Whereas our mean t_{lim95} was shorter than ten minutes, mean time to exhaustion during intermittent exercise in Thevenet et al. [6] study was much longer because of the exercise modality. If decrease is linked to respiratory muscle fatigue, it could confirm results of Jonhson et al. [23] who recommended exercise intensity and duration at less of 85% of MAV and ten minutes respectively to induce respiratory muscle fatigue. We thought that 95% of MAV was an appropriate intensity in order to run longer than ten minutes, but it seems to be necessary to choose lower intensities or other exercise modality to run longer and then support the respiratory muscle fatigue hypothesis. These observations are consistent with conclusions of Romer et Polkey who suggested that exercise intensity is important but also that exercise duration plays a major role in diaphragm fatigue [24].

The second approach was based on the use of V_T, fr and $\dot{V}_E$ kinetics [9]. Let us first note that the filtering process used to analyse $\dot{V}O_2$ kinetics cannot be used in those cases. Indeed, $\dot{V}_E$ and fr kinetics do not fit a second order model. For example, no stable state is reached before exhaustion. Our results showed that the decrease in $\dot{V}_E$ began at around 95% of t_{lim95}. This result could be explained by a V_T decrease. Indeed, after 95% of t_{lim95}, the increase in fr seemed to be insufficient to prevent the V_T decrease, that can be considered as an indirect sign of respiratory muscle fatigue [9] and can partly explain the $\dot{V}O_2$ decrease [6] before exhaustion. Nevertheless, the absence of significantly different results on respiratory muscle fatigue and the impossibility of statistical processing $\dot{V}_E$, V_T and fr values, lead us to consider our results with caution and to partly reject our hypothesis. Another hypothesis has been advanced by Perrey et al. [2] to explain the origin of the $\dot{V}O_2$ decrease before exhaustion. This hypothesis is related to a cardiac output decrease and to an O_2 arterio-veinous difference decrease. The latter hypothesis seems to be more likely during a maximal exercice and could have an influence on the locomotor muscles perfusion and $\dot{V}O_2$ for trained athletes. Indeed, during a maximal exercise, respiratory muscles O_2 consumption corresponds to 10-15% of $\dot{V}O_{2max}$. It induces a greater respiratory muscle blood flow, which could in turn induce locomotor muscle vasoconstriction. Then, it could compromise the blood flow, necessary for a good perfusion of locomotor muscles, and decrease the O_2 arterio-veinous difference [25]. An exercise-induced hypoxaemia (EIH) could also explain an O_2 arterio-veinous difference decrease. EIH is defined as a reduction in the arterial pressure O_2 (PaO_2) by more than 1kPa and/or a haemoglobin O_2 saturation (SaO_2) below 95% [26]. The ability to maintain a high alveolar O_2 pressure (PAO_2) is critical for blood oxygenation and this appears to be difficult in large individuals. A large lung capacity and, in turn, diffusion capacity seem to protect PaO_2. A widening of the PAO_2-PaO_2 difference does indicate that a diffusion limitation, a ventilation-perfusion mismatch and/or a shunt influence the transport of O_2 from alveoli to the pulmonary capillaries. A marked increase in cardiac output induces a faster transit time. When the latter is combined with diffusion limitation previously described, the O_2 transport problem is accentuated. To conclude, the existence of a $\dot{V}O_2$ decrease before the end of the exercise, already highlighted in the literature [2, 3, 4], seems to be confirmed. However, the respiratory muscle fatigue hypothesis seems to be partly rejected to explain our results. We suppose, indeed, that the exercise duration was insufficient to induce a respiratory muscle fatigue in the subjects. It could be interesting hence, to test other exercise intensities or modalities, in order to study respiratory muscle fatigue and its link with $\dot{V}O_2$ decrease over a longer period.

Limitations

Whilst this study examined only eight male physical education students, studying more high-level middle and long-distance runners is certainly warranted to get a better understanding of the nature of the associations between the $\dot{V}O_2$ decrease and the respiratory muscle fatigue.

Aknowledgement

In memory of Delphine Thevenet.

Conflict of Interests

The authors have no conflicts of interest that are directly relevant to the content of this article.

REFERENCES

1. Poole DC, Ferreira LF, Behnke BJ, Barstow TJ, Jones AM. The final frontier: oxygen flux into muscle at exercise onset. Exerc Sport Sci Rev. 2007;35(4):166-173.
2. Perrey S, Candau R, Millet GY, Borrani F, Rouillon JD. Decrease in oxygen uptake at the end of a high-intensity submaximal running in humans. Int J Sports Med. 2002;23(4):298-304.
3. Astrand PO, Saltin B. Oxygen uptake during the first minutes of heavy muscular exercise. J Appl Physiol. 1961;16:971-976.
4. Nummela A, Rusko H. Time course of anaerobic and aerobic energy expenditure during short-term exhaustive running in athletes. Int J Sports Med. 1995;16(8):522-527.
5. Heubert R, Bocquet V, Koralsztein JP, Billat V. Effect of 4 weeks of training on the limit time at VO_{2max}. Can J Appl Physiol. 2003; 28(5):717-736.
6. Thevenet D, Tardieu-Berger M, Berthoin S, Prioux, J. Influence of recovery mode (passive vs. active) on time spent at maximal oxygen uptake during an intermittent session in young and endurance-trained athletes. Eur J Appl Physiol. 2007;99(2):133-142.
7. Worshop NHLBI. Respiratory muscle fatigue: report of the respiratory muscle fatigue worshop group. Am Rev Respir Dis. 1990;142:474-486.
8. Black LF, Hyatt RE. Maximal static respiratory pressures in generalized neuromuscular disease. Am Rev Respir Dis. 1971;103(5) 641-650.
9. Gallagher CG, Hof VI, Younes ME. Effect of inspiratory muscle fatigue on breathing pattern. J Appl Physiol. 1985; 59(4):1152-1158.
10. Tardieu-Berger M, Thevenet D, Zouhal H, Prioux J. Effects of active recovery between series on performance during an intermittent exercise model in young endurance athletes. Eur J Appl Physiol. 2004;93(1-2):145-152.
11. McLaughlin JE, King GA, Howley ET, Bassett DR, Ainsworth BE. Validation of the COSMED K4b2 portable metabolic system. Int J Sports Med. 2001;22(4):280-284.
12. Pinnington HC, Wong P, Tay J, Green D, Dawson B. The level of accuracy and agreement in measures of FEO2, FECO2 and VE between the Cosmed K4b2 portable, respiratory gas analysis system and a metabolic cart. J Sci Med Sport. 2001;4:324-335.
13. Supinski G, Fitting J, Bellemare F. Assessment of respiratory muscle fatigue. Am J Respir Crit Care Med. 2002;166:571-579.
14. Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. Am Rev Respir Dis. 1969;99(5):696-702.
15. Matecki S, Prioux J, Amsallem F, Denjean A, Ramonatxo M. Maximal respiratory pressures in children: the methodological challenge. Rev Mal Respir. 2004; 21(6):1116-1123.
16. Matecki S, Prioux J, Jabert S, Hayot M, Prefaut C, Ramonatxo M. Respiratory pressure in boys from 11 to 17 years old: a semi longitudinal study. Pediat Pulmonol. 2003;35:368-374.
17. Léger L, Boucher R. An indirect continuous running multistage field test: the Université de Montréal track test. Can J Appl Sport Sci. 1980;5(2):77-84.
18. Basseville M, Nikiforov IV. Detection of abrupt changes - Theory and application. Prentice-Hall, Inc. 1993.
19. Batterham AM, Hopkins WG. Making meaningful inferences about magnitudes. International journal of sports physiology and performance. 2006;1(1):50-57.
20. Hayot M, Matecki S. Respiratory muscle fatigue: an update. Rev Mal Respir. 2004;21(4):840-844.
21. Leech JA, Ghezzo H, Stevens D, Becklake MR. Respiratory pressures and function in young adults. Am Rev Respir Dis. 1983;128(1):17-23.
22. Chen HI, Kuo CS. Relationship between respiratory muscle function and age, sex, and other factors. J Appl Physiol.1989;66(2):943-8.
23. Johnson BD, Babcock MA, Suman OE, Dempsey JA, Exercise-induced diaphragmatic fatigue in healthy humans. J Physiol. 1993;460: 385-405.
24. Romer LM, Polkey MI. Exercise-induced respiratory muscle fatigue: implications for performance. J Appl Physiol. 2008;104(3):879-88.
25. Harms CA, Babcock MA, McClaran SR, Pegelow DF, Nickele GA, Nelson WB, Dempsey JA. Respiratory muscle work compromises leg blood flow during maximal exercise. J Appl Physiol. 1997;82(5):1573-83.
26. Nielsen H, Arterial desaturation during exercise in man: implication for O_2 uptake and work capacity. Scand J Med Sci Sports. 2003; 13(6):339-58.

The Swedish Journal of Scientific Research

Original Article

Does Melatonin Supplementation Affect Renal Function in Healthy Humans during Prolonged Exercise?

Amine Souissi[1]*, Narimen Yousfi[2], Mehdi Rouissi[2], Taieb Messaoud[3], Nafaa Souissi[4], Abderraouf Ben Abderrahmen[5], Nizar Souissi[6]

[1]Unit "Sport Performance, Health & Society, Higher Institute of Sport and Physical Education, Ksar Saîd University of "La Manouba," Tunis, Tunisia, [2]Research Laboratory "Sport Performance Optimization", National Centre of Medicine and Science in Sport. Tunis, Tunisia, [3]Laboratory of Biochemistry and Molecular Biology, Children's Hospital of Tunis, Tunisia, [4]Biomechanics Laboratory, National Institute of Orthopedics "M.T. Kassab", Tunis, Tunisia, [5]Higher Institute of Sport and Physical Education of Ksar-Said, Tunisia, [6]Research Unit Physical Activity, Sport & Health, National Observatory of Sports, Tunis, Tunisia

ABSTRACT

Prolonged submaximal exercise induces reductions in vascular conductance to splanchnic and renal circulations. We aimed to evaluate in the present study the effect of melatonin on the renal response to submaximal exercise. Eight students aged between 20-23 years participated in the study. They ran at 60% of their maximal aerobic speed (MAS) for 45min after 50min of either melatonin-(6mg) or placebo ingestion, in a randomized order. The rectal temperature (Tre) and heart rate (HR) were measured. Felt arousal scale was measured at the beginning and at the end of the rest. Blood samples were taken before and after exercise, from which the hemoglobin (Hb), hematocrit (Hct), sodium (Na+), potassium (K+), bicarbonate (HCO_3^-), pH, urea, uric acid, creatinine, parathyroid hormone (PTH), calcium (Ca^{2+}), chloride (Cl^-), phosphor (P) and vitamin D concentrations were measured. Creatinine clearance was calculated based on the Cockcroft-Gault equation. Hb and Hct increased after exercise only in the placebo condition. Our results showed that T_{re} increased significantly at the end of exercise in both conditions ($P < 0.001$). HR was significantly attenuated in melatonin condition at the end of the exercise ($P < 0.01$). There was no statistical difference in creatinine clearance between conditions, but PTH was significantly higher in melatonin condition compared to placebo (68.6 and 51.9; $P = 0.01$) at the end of the exercise. Our finding revealed that melatonin increases the extent of the exercise-induced increase in PTH. We suggest that melatonin induce renal vasoconstriction during prolonged exercise owing to the alteration of renal blood flow.

Keywords: Exercise, kidney, melatonin, temperature, creatinine clearance, vasoconstriction

INTRODUCTION

Prolonged submaximal exercise is accompanied by an increase in body core temperature and elevation in cardiovascular strain (e.g. a rise in heart rate) and perceived exertion [1]. Therefore, the ability to maintain a given power output or running velocity progressively declines [2]. Typically, the human body's temperature is controlled by thermoregulatory reflexes (Vasoconstriction and vasodilatation) which allows for heat to be conserved or dissipated to the environment by way of conduction, convection, radiation, and evaporation [3]. Whole body pre-cooling strategies such as cold air, water immersion, water-perfused suits aim to reduce body temperature before exercise, thereby increasing the margin for metabolic heat

Access this article online

Website: http://sjsr.se/

ISSN: 2001-9211

Address for correspondence:
Amine Souissi, Unit "Sport Performance, Health & Society, Higher Institute of Sport and Physical Education, Ksar Saîd University of "La Manouba," Tunis, Tunisia. Tel.: +216 99 414 452. E-mail: amine.swissi@gmail.com

production and increasing the time to exhaustion or the distance run or cycled [4]. These aforementioned strategies are worthwhile if the facilities are available. However, it's not always the case. In this context, nutritional strategies with antioxidants have been proposed to protect the body against oxidative stress and core temperature increase during exercise [5].

Melatonin (N-acetyl-5-methoxytryptamine), a hormone secreted by the pineal gland, acts as the major regulator of the circadian rhythm of core temperature in humans [6]. However, some unfavourable effects of this hormone such as increasing the blood pressure owing to down regulation of nitric oxide synthase (NOS) [7-9] and constrict the renal arteries in humans have been reported [10], which could induce a substantial drop in glomerular filtration rate and may cause renal failure [11,12]. Several studies have examined the hypothermic effect of melatonin, demonstrating a 0.25°C to 0.3°C decline in core temperature within several hours of consuming up to 5 mg dose [13,14]. Data available related to melatonin supplementation and exercise are limited and they are focused mainly on body temperature [15].

Few studies have examined the effects of exogenous melatonin supplementation on sports performance. Indeed, Atkinson et al (2005) examined the effects of melatonin supplementation on short term athletic performance, reporting no significant improvement in grip strength, 4 km cycling time or RPE despite the significant reductions in intra-aural temperature [16]. This study provides evidence that melatonin does not significantly affect absolute short term power output; however, there is little evidence available on its effect on continuous exercise performance. To our knowledge, all the studies investigated the effect of melatonin supplementation on continuous exercise performance found no effect on performance [16,17]. In the same context, it was shown that melatonin (5 mg) has no hypothermic effect during continuous exercise in hyperthermia [18].

Previous research from our laboratory showed also that 6mg of melatonin has no hypothermic effect during continuous exercise in normothermia [19]. Evidence suggests that melatonin does not attenuate the increase of rectal temperature during continuous exercise. The biological parameters analyzed in our previous researches focused mainly on inflammatory biomarkers and biological parameters indicators of sweating. To the best of our knowledge, no studies have evaluated the effect of melatonin (>5mg) on the biological markers of the renal function. Since melatonin has been demonstrated to reduce renal blood flow in humans, we hypothesized that increases in melatonin would alter renal function at rest and during exercise.

METHODS

Study Design and Participants

Eight healthy, moderately trained male students [age: 21.8 ± 0.9 years; BMI: 21 ± 0.8] from the local higher institute of sport and physical education voluntarily participated in the study. After receiving a description of the protocol, risks of the study, each participant reviewed and signed a written informed consent form prior to participation. The study protocol complied with the Helsinki declaration for human experimentation and the protocol was fully approved by the local Ethics Committee on Human Research. All athletes reported being nonsmokers and not consuming alcohol and/or any antioxidant compounds, including neither vitamins nor medications (e.g. anti-inflammatory drugs or hypnotic agents).

The participants were screened by obtaining a medical history, including any history of severe physical or mental disorders, and performing physical examinations. During the first appointment, maximal aerobic speed (MAS) was assessed using the VAMEVAL test at 09:50 [20]. The second and third appointments were devoted to completing the two sessions of the protocol (melatonin or placebo) in a randomized order. All physical tests were performed at a temperature of 23 ± 0.1°C (maintained with a programmable temperature controller) and a relative humidity of 60% ± 3%. The participants were not specifically heat acclimated when they exercised for 45 min at 60% MAS.

Experimental Protocol

A rectal thermistor was inserted into the athletes (inserted 10 cm beyond the anal sphincter). At 09:00, the participants ingested either the melatonin or placebo capsule with water (500 ml) and then rested for 40 min in the dorsal position. During this period, the rectal temperature (T_{re}) and heart rate (HR) were recorded continuously with a HR monitor (Polar RS800, Finland) and a rectal probe (Universal YSI400, China). At 09:40, a blood sample was taken. At 09:50, the

participants started the exercise on a treadmill (Finnlo, Germany). They ran for 45 min at a submaximal intensity fixed at 60% of their MAS. Their HR and T_{re} were recorded continuously during all the period of rest and exercise (the data were selected at the beginning and the end of the exercise).

Blood samples were taken before and after exercise, from which the hemoglobin (Hb), hematocrit (Hct), sodium (Na+), potassium (K+), bicarbonate (HCO_3^-), pH, urea, uric acid, creatinine, parathyroid hormone PTH, calcium (Ca^{2+}), chloride (Cl^-), phosphor (P) and vitamin D concentrations were measured. Felt arousal scale (FAS) was measured at the beginning and at the end of the rest. The rating of perceived exertion (RPE) was measured using a modified Borg scale [21].

Biochemical Analyses

Biochemical assays were performed using standard techniques at the Laboratory of the Hospital of Children in Tunis, Tunisia, using the COBAS 6000. The total 25 OH vitamin D and PTH concentration was measured with electrochemiluminescence (ECLIA) on an automated Roche Cobas E 411 (Roche Diagnostics).

Statistical Analyses

Statistical Software Version 10.0 for Windows (StatSoft, Maisons-Alfort, France) was used for data analysis. The data are reported as the mean and standard deviation (± SD). Concerning the variables measured at the beginning and the end of the rest, the data were analyzed using repeated measures (condition × time) analysis of variance (ANOVA). The Bonferroni test was used to identify significant differences. Concerning the variables measured only at the end of the exercise, the data were analyzed using a paired Student's t-test. Effect sizes were calculated as partial eta-squared (η_p^2) to assess the practical significance of our findings. The level of significance was predetermined to be $P < 0.05$ for all statistical analyses.

RESULTS

Heart Rate and Rectal Temperature

The mean values of resting T_{re} and HR are displayed in Table 1. Post-hoc analysis revealed that HR was significantly higher at the end of exercise in placebo condition than melatonin condition (3.6%; $P < 0.01$) (Table 2).

Felt Arousal Scale and RPE

The mean values of the FAS are displayed in Tables 1. A significant interaction (condition × rest) was indicated for the FAS [$F = 43.75$, $P < 0.001$, $\eta_p^2 = 0.8$]. Post hoc analysis indicated that melatonin considerably decreased the level of arousal ($P < 0.001$) at rest. The T-test of student revealed a significant difference in RPE at the end of exercise between conditions. At the end of the exercise, the RPE was more elevated for the melatonin condition than for the placebo condition (13%; $P < 0.001$) (Table 2).

Hb, Hct, [La], Urea, Uric Acid, Bicarbonate, Ph, Creatinine and Creatinine Clearance

The mean [La] values for both conditions were less than 2.5 mmol/L. Post hoc analysis indicated that the Hb and Hct increased after exercise only in placebo condition (respectively, with $P = 0.01$ and $P = 0.011$) (Table 3). The mean values of urea,

Table 1: The physiological and psychological variable results at rest for both conditions

Variable		Placebo		Melatonin		Global effect
		0_{min}	40_{min}	0_{min}	40_{min}	
HR (beats/min)	*Mean*	66.7	58.3	69	57.2	Condition: NS
	SD	8.7	7.6 *	8.3	6.9 *	Rest: *** Interaction: *
T_{re} (°C)	*Mean*	37.22	37.01	37.43	37.02	Condition: NS
	SD	0.19	0.18 *	0.15	0.16 *	Rest: *** Interaction: **
FAS	*Mean*	5	4.75	5.12	2.3	Condition: **
	SD	1.06	1.28	0.83	0.51 *§	Rest: *** Interaction: ***

*: Significant difference from the pre-exercise value ($p < 0.05$)
§: Significant difference from the placebo condition ($p < 0.05$)
NS: Non significant ($p > 0.05$)

Table 2: The pre- and post-exercise results of the physiological and psychological variables for both conditions

Variable		Placebo		Melatonin		Global effect
		0_{min}	45_{min}	0_{min}	45_{min}	
HR (beats/min)	*Mean*	68.3	165.5	66.2	159	Condition: *
	SD	6.2	5.5 *	7.5	3.7 *§	Exercise: *** Interaction: **
T_{re} (°C)	*Mean*	37.04	38.42	36.97	38.69	Condition: NS
	SD	0.17	0.22 *	0.20	0.37 *	Exercise: *** Interaction: **
RPE	*Mean*		13.12		14.87	Condition: ***
	SD		2.23		1.95 §	

*: Significant difference from the pre-exercise value ($p < 0.05$)
§: Significant difference from the placebo condition ($p < 0.05$)
NS: Non significant ($p > 0.05$)

uric acid, bicarbonate, pH, creatinine and estimated creatinine clearance are displayed in Table 3. The creatinine clearance was estimated by Cockcroft-Gault equation [22].

CreatClear = ((140 - Age)/(SerumCreat)) * (Weight/72)

No significant (condition × exercise) interaction was obtained for urea [F = 4.06, P = 0.08, η_p^2 = 0.36]. Post-hoc analysis revealed that urea increased only in melatonin condition after exercise (P= 0.004). A significant (condition x exercise) interaction was obtained for uric acid [F = 8, P = 0.025, η_p^2 = 0.53]. Post-hoc analysis revealed that uric acid was significantly higher under melatonin than placebo condition at rest (P < 0.001) and at the end of the exercise (P < 0.0001). No significant (condition × exercise) interaction was obtained for creatinine [F = 0.71, P = 0.42, η_p^2 = 0.09]. No significant (condition × exercise) interaction was obtained for creatinine clearance [F = 0, P = 1, η_p^2 = 0]. No significant (condition × exercise) interaction was obtained for bicarbonate [F = 0.003, P = 0.95, η_p^2 < 0.001]. No significant (condition × exercise) interaction was obtained for pH [F = 1.3, P = 0.28, η_p^2 = 0.16].

Table 3: The pre- and post-exercise biochemical parameter results for the two conditions

Variable		Placebo		Melatonin		Global effect
		0_{min}	45_{min}	0_{min}	45_{min}	
Hb (g/dl)	*Mean* *SD*	14.3 0.5	15 0.7 *	14.2 0.6	14.4 0.5 §	Condition: NS Exercise: *** Interaction: NS
Hct (%)	*Mean* *SD*	43 1.5	45.5 2.1 *	42.3 2	43.3 1.4 §	Condition: * Exercise: *** Interaction: NS
Na+ (mmol/l)	*Mean* *SD*	139 1.3	140 1.2	139 1.2	140 1.7	Condition: NS Exercise: NS Interaction: NS
K+ (mmol/l)	*Mean* *SD*	4.4 0.2	4.4 0.1	4.2 0.1	4.4 0.1	Condition: NS Exercise: NS Interaction: NS
Urea (µmol/l)	*Mean* *SD*	5.25 1.3	5.37 1.24	5.67 1.23	5.92 1.2	Condition: NS Exercise: ** Interaction: NS
Uric acid (µmol/l)	*Mean* *SD*	295 58	304 58	304 55	318 52	Condition: NS Exercise: ** Interaction: *
Creatinine (µmol/l)	*Mean* *SD*	74.2 4.6	79.8 2.9	74.6 5.6	79.1 4.4	Condition: NS Exercise: ** Interaction: NS
CreatClear	*Mean* *SD*	130 14	120 8.5	131 11.8	121 10.8	Condition: NS Exercise: * Interaction: NS
HCO_3^-(mmol/l)	*Mean* *SD*	27.9 2.7	27.3 3.1	27.9 2.8	27.3 2.6	Condition: NS Exercise: NS Interaction: NS
pH	*Mean* *SD*	7.44 0.03	7.43 0.04	7.44 0.03	7.45 0.01	Condition: NS Exercise: NS Interaction: NS
[La] (mmol/l)	*Mean* *SD*	1.8 0.3	2 0.5	1.7 0.4	1.8 0.4	Condition: NS Exercise: NS Interaction: NS

*: Significant different from corresponding pre-exercise value (p<0.05)
§: Significant different from placebo condition (p<0.05)
NS: Non-significant (p>0.05)

Parathyroid Hormone, Calcium, Chloride, Phosphor and Vitamin D

The mean values of plasmatic PTH, calcium, chloride, phosphor and vitamin D are displayed in Table 4. A significant (condition x exercise) interaction was obtained for PTH [F = 20.55, P < 0.01, η_p^2 = 0.7]. Post-hoc analysis revealed that PTH was significantly higher in melatonin condition compared to placebo condition at the end of the exercise (32%; P = 0.01). A significant (condition x exercise) interaction was obtained for calcium [F = 35.32, P < 0.001, η_p^2 = 0.8]. A significant (condition x exercise) interaction was obtained for chloride [F = 5.9, P < 0.046, η_p^2 = 0.45]. A significant (condition x exercise) interaction was obtained for vitamin D [F = 6.26, P = 0.04, η_p^2 = 0.47]. No significant (condition × exercise) interaction was obtained for phosphor [F = 1.1, P = 0.32, η_p^2 = 0.13].

Table 4: Pre and post exercise result for biochemical parameter and inflammatory biomarkers

Variable		Placebo		Melatonin		Global effect
		0_{min}	45_{min}	0_{min}	45_{min}	
PTH (pg/mL)	*Mean* *SD*	27.8 7.5	51.9 18.3 *	29.6 6	68.6 20.6 *§	Condition: *** Exercise: *** Interaction: **
Ca^{2+} (mmol/l)	*Mean* *SD*	2.41 0.06	2.52 0.08 *	2.40 0.05	2.42 0.06	Condition: * Exercise: *** Interaction: ***
Cl^- (mmol/l)	*Mean* *SD*	99.7 1.4	100.5 0.8	99.4 1.1	100.7 1.3	Condition: NS Exercise: * Interaction: *
P (mmol/l)	*Mean* *SD*	1.06 0.07	1.35 0.13	1.05 0.14	1.27 0.11	Condition: NS Exercise: ** Interaction: NS
Vit.D (ng/ml)	*Mean* *SD*	21.5 9	*24.2 9.4	22.5 8.7	*21.9 7.8	Condition: NS Exercise: NS Interaction: *

*: Significant difference from the pre-exercise value (p < 0.05)
§: Significant difference from the placebo condition (p < 0.05)
NS: Non significant (p > 0.05)

DISCUSSION

The purpose of this study was to investigate for the first time the effects of a single dose (6 mg) of melatonin on renal response to continuous, submaximal exercise. Our study is the first study investigating the effect of a single dose of melatonin (>5mg) on renal response to continuous exercise. The main finding of our study is that a single 6 mg dose of melatonin increased PTH but did not affect glomerular filtration at the end of the exercise.

Our finding indicated that melatonin expand the exercise-induced increasing in PTH, is known to be a vasodilator and to exert a hypotensive action to induce a reduction in BP [23]., Brickman et al. (1991) recently demonstrated that there was a positive relation between PTH and BP in nonhypertensive subjects [24]. Moreover, since the renal vasoconstriction, occurs during prolonged exercise might, increases renal blood pressure (BP) and parathyroid hormone (PTH). A positive relation between PTH and BP has been demonstrated in nonhypertensive subjects [24] PTH is known to be a vasodilator and to exert a hypotensive action to induce a reduction in BP [23]. Authors could speculate that the important increase of PTH in melatonin condition is due to an important elevation in BP. In this context, the results of the present study support the results of Cook et al.(2011) indicating that melatonin constrict the renal arteries and increase BP. Otherwise, authors suggest that PTH seems to counteract elevation of BP induced by renal vasoconstriction during prolonged exercise and increase glomerular filtration.

On the other hand, our finding revealed that melatonin decreased significantly FAS at rest. Previous research demonstrated that melatonin decreases regional cerebral blood flow in the rat [25], but not in humans [10,26]. Thus, we speculate that melatonin does not have an acute regulatory effect on cerebral blood flow in humans. Further studies were needed to investigate the effect of melatonin on cerebral blood flow in athletes after exercise. High dose of melatonin induces renal vasoconstriction and increase BP, but the mechanisms of its hypertensive actions are not well understood. Melatonin increases renal blood pressure by increasing the renal sympathetic outflow [10] and/or by its NO-scavenging action [7,8,27]. Nitric oxide synthase (NOS) activity was inhibited in a dose-dependent manner by physiological concentrations of melatonin [28,29]. The NO-scavenging action of melatonin induces vasoconstrictor activity [30,31] and may affect inflammatory response to prolonged continuous exercise [20]. The effect of exogenous melatonin on blood pressure appears to be dose related. Melatonin functions differently within the body depending on the ingested dose [10,32-34]. Research in animals confirms a dose response to melatonin concentration in relation to vascular changes [35,36], adrenal nerve activity [37], and hormonal secretion responses [38].

In fact, exercise increases the HR, which will almost certainly enhance the mechanical forces of blood flow, such as shear stress, pressure, and cyclic strain, on the vascular wall [39]. In conductance arteries, shear stress has been shown to increase endothelial superoxide generation [40]. Prolonged sustained high levels of shear stress, as encountered during exercise as a result of increased cardiac output, have been shown to stimulate NO production, hydrogen peroxide and vascular superoxide production [41]. NO, when produced in large amounts, binds O_2 to form peroxynitrite (ONOO−), an unstable compound that decomposes into toxic hydroxyl radicals [42]. High production of superoxide and NO affect the antioxidant defense. Therefore, because of the low antioxidant defense, prolonged periods of exercise (or intensive exercise) induce an increase in vascular oxidative stress, which is considered a pathogenic factor that induces cardiac fatigue [39] and renal inflammation [43].

We suggest that the administration of low dose of melatonin just before exercise could improve cardiovascular and renal function during exercise by reducing vascular oxidative stress and the production of ONOO− in the endothelium, which increases NO bioavailability, reduces inflammation, favors vasorelaxation and improves cardiac force and renal function. Furthermore, patients of older age have significantly higher NO and peroxynitrite levels [44] and melatonin could be helpful for elderly people and for patients who suffer from chronic diseases.

A limitation of the present study is that we used maximal aerobic speed rather than maximal oxygen uptake (VO2max). Moreover, the study was conducted only on male athletes. Therefore, different finding might be among female. The sweet loss was more important in the placebo condition than melatonin condition. Therefore, the results of the present study may underestimate the true perturbation of the renal

function that melatonin could induce during exercise. Finally, melatonin (NO-scavenger) competitively inhibits NO-production but it will be interesting to confirm that with analyze of circulating NO. It is difficult to analyze NO due to its volatile nature.

CONCLUSION

The data of this study showed that a single dose (6mg) of melatonin supplementation increases the extent of exercise-induced increase in PTH. Thus, we suggest that the administration of high dose (≥6mg) of melatonin before exercise might disturb the renal function because of its vasoconstrictor effect. The present study sends a warning signal to the acute use of very high dose of melatonin as a dietary supplement before exercise.

ACKNOWLEDGMENTS

The authors wish to express their sincere gratitude to all the participants for their cooperation. We are thankful to Mr. Noureddine Souissi (a staff Engineer) for his technical assistance.

Declaration of interests

This study was supported by The Laboratory of Biochemistry and Molecular Biology, Children's Hospital in Tunis, Tunisia. The author declares that there are no conflicts of interest.

REFERENCES

1. Rowell, L.B., *Human cardiovascular adjustments to exercise and thermal stress.* Physiol Rev, 1974. **54**(1): p. 75-159.
2. Atkinson, G., et al., *Effects of melatonin on the thermoregulatory responses to intermittent exercise.* J Pineal Res, 2005. **39**(4): p. 353-9.
3. Rivas, E., et al., *The change in metabolic heat production is a primary mediator of heat acclimation in adults.* J Therm Biol, 2017. **70**(Pt B): p. 69-79.
4. Marino, F.E., *Methods, advantages, and limitations of body cooling for exercise performance.* Br J Sports Med, 2002. **36**(2): p. 89-94.
5. Pingitore, A., et al., *Exercise and oxidative stress: potential effects of antioxidant dietary strategies in sports.* Nutrition, 2015. **31**(7-8): p. 916-22.
6. Gandhi, A.V., et al., *Melatonin is required for the circadian regulation of sleep.* Neuron, 2015. **85**(6): p. 1193-9.
7. Silva, C.L., et al., *Melatonin inhibits nitric oxide production by microvascular endothelial cells in vivo and in vitro.* Br J Pharmacol, 2007. **151**(2): p. 195-205.
8. Tamura, E.K., C.L. Silva, and R.P. Markus, *Melatonin inhibits endothelial nitric oxide production in vitro.* J Pineal Res, 2006. **41**(3): p. 267-74.
9. Okatani, Y., et al., *Weak vasoconstrictor activity of melatonin in human umbilical artery: relation to nitric oxide-scavenging action.* European journal of pharmacology, 2001. **417**(1-2): p. 125-129.
10. Cook, J.S., C.L. Sauder, and C.A. Ray, *Melatonin differentially affects vascular blood flow in humans.* Am J Physiol Heart Circ Physiol, 2011. **300**(2): p. H670-4.
11. West, J.R., H.W. Smith, and H. Chasis, *Glomerular filtration rate, effective renal blood flow, and maximal tubular excretory capacity in infancy.* J Pediatr, 1948. **32**(1): p. 10-8.
12. Radigan, L.R. and S. Robinson, *Effects of environmental heat stress and exercise on renal blood flow and filtration rate.* J Appl Physiol, 1949. **2**(4): p. 185-91.
13. Cagnacci, A., J.A. Elliott, and S.S. Yen, *Melatonin: a major regulator of the circadian rhythm of core temperature in humans.* J Clin Endocrinol Metab, 1992. **75**(2): p. 447-52.
14. Sack, R.L., et al., *Sleep-promoting effects of melatonin: at what dose, in whom, under what conditions, and by what mechanisms?* Sleep, 1997. **20**(10): p. 908-15.
15. Acuna Castroviejo, D., et al., *Melatonin-mitochondria interplay in health and disease.* Curr Top Med Chem, 2011. **11**(2): p. 221-40.
16. Atkinson, G., et al., *Effects of daytime ingestion of melatonin on short-term athletic performance.* Ergonomics, 2005. **48**(11-14): p. 1512-22.
17. Brandenberger, K.J., et al., *Consumption of a 5-mg Melatonin Supplement Does Not Affect 32.2-km Cycling Time Trial Performance.* J Strength Cond Res, 2018. **32**(10): p. 2872-2877.
18. McLellan, T.M., et al., *Melatonin has no effect on tolerance to uncompensable heat stress in man.* Eur J Appl Physiol, 2000. **83**(4 -5): p. 336-43.
19. Souissi, A., et al., *Effect of acute melatonin administration on physiological response to prolonged exercise.* Biological Rhythm Research, 2019: p. 1-8.
20. Souissi, A., et al., *Effect of melatonin on inflammatory response to prolonged exercise.* Biological Rhythm Research, 2018: p. 1-6.
21. Borg, G.A., *Psychophysical bases of perceived exertion.* Med Sci Sports Exerc, 1982. **14**(5): p. 377-81.
22. Cockcroft, D.W. and M.H. Gault, *Prediction of creatinine clearance from serum creatinine.* Nephron, 1976. **16**(1): p. 31-41.
23. Saglikes, Y., et al., *Effect of PTH on blood pressure and response to vasoconstrictor agonists.* Am J Physiol, 1985. **248**(5 Pt 2): p. F674-81.
24. Brickman, A., et al., *Parathyroid hormone, platelet calcium, and blood pressure in normotensive subjects.* Hypertension, 1991. **18**(2): p. 176-82.
25. Capsoni, S., B. M. Stankov, and F. Fraschini, *Reduction of regional blood flow by melatonin in young rats.* Vol. 6. 1995. 1346-8.
26. H M van der Helm-van Mil, A., et al., *No Influence of Melatonin on Cerebral Blood Flow in Humans.* Vol. 88. 2004. 5989-94.
27. Mount, P.F. and D.A. Power, *Nitric oxide in the kidney: functions and regulation of synthesis.* Acta Physiol (Oxf), 2006. **187**(4): p. 433-46.
28. Khdhr, A.R. and A.M. Mahmud, *Protective Role of Melatonin in L-Name Induced Hypertension in Male Albino Rats.* Science Journal of University of Zakho, 2016. **4**(1): p. 18-24.
29. Pozo, D., et al., *Physiological concentrations of melatonin inhibit nitric oxide synthase in rat cerebellum.* Life Sci, 1994. **55**(24): p. Pl455-60.
30. Geary, G.G., S.P. Duckles, and D.N. Krause, *Effect of melatonin in the rat tail artery: role of K+ channels and endothelial factors.* Br J Pharmacol, 1998. **123**(8): p. 1533-40.
31. Okatani, Y., et al., *Weak vasoconstrictor activity of melatonin in human umbilical artery: relation to nitric oxide-scavenging action.* Eur J Pharmacol, 2001. **417**(1-2): p. 125-9.
32. Arangino, S., et al., *Effects of melatonin on vascular reactivity, catecholamine levels, and blood pressure in healthy men.* Am J Cardiol, 1999. **83**(9): p. 1417-9.
33. Cagnacci, A., et al., *Influences of melatonin administration on the circulation of women.* Am J Physiol, 1998. **274**(2 Pt 2): p. R335-8.
34. Ray, C.A., *Melatonin attenuates the sympathetic nerve responses to orthostatic stress in humans.* The Journal of physiology, 2003. **551**(Pt 3): p. 1043-1048.
35. Doolen, S., et al., *Melatonin mediates two distinct responses in vascular smooth muscle.* Eur J Pharmacol, 1998. **345**(1): p. 67-9.
36. Ting, N., et al., *Pharmacological studies on the inhibitory action of melatonin and putative melatonin analogues on porcine vascular smooth muscle.* Naunyn Schmiedebergs Arch Pharmacol, 2000. **361**(3): p. 327-33.

37. Niijima, A., et al., *Effect of intravenous administration of melatonin on the efferent activity of the adrenal nerve*. J Auton Nerv Syst, 1998. **71**(2-3): p. 134-8.
38. Forsling, M.L., M.J. Wheeler, and A.J. Williams, *The effect of melatonin administration on pituitary hormone secretion in man*. Clin Endocrinol (Oxf), 1999. **51**(5): p. 637-42.
39. Kojda, G. and R. Hambrecht, *Molecular mechanisms of vascular adaptations to exercise. Physical activity as an effective antioxidant therapy?* Cardiovasc Res, 2005. **67**(2): p. 187-97.
40. Laurindo, F.R., et al., *Vascular free radical release. Ex vivo and in vivo evidence for a flow-dependent endothelial mechanism*. Circ Res, 1994. **74**(4): p. 700-9.
41. Lauer, N., et al., *Critical involvement of hydrogen peroxide in exercise-induced up-regulation of endothelial NO synthase*. Cardiovasc Res, 2005. **65**(1): p. 254-62.
42. Grzelak, A., E. Macierzynska, and G. Bartosz, *Melatonin does not react rapidly with hydrogen peroxide*. Free Radic Res, 2004. **38**(11): p. 1155-8.
43. Manning, R.D., Jr., S. Meng, and N. Tian, *Renal and vascular oxidative stress and salt-sensitivity of arterial pressure*. Acta Physiol Scand, 2003. **179**(3): p. 243-50.
44. Kouti, L., et al., *Changes of Nitric Oxide and Peroxynitrite Serum Levels during Drug Therapy in Patients with Obsessive-Compulsive Disorder*. Advances in medicine, 2016. **2016**: p. 9131680-9131680.

The Swedish Journal of Scientific Research

Original Investigation

Physical Characteristics and Strength Ratios Differentiating Starter vs. Non-starter Elite Youth Soccer Players

Mehdi Rouissi[1]*, Adam Lee Owen[2,3], Nicola Luigi Bragazzi[4], Sinda Ben Achour[5], Karim Chamari[6]

[1]Tunisian Research Laboratory "Sport Performance Optimization", National Center of Medicine and Science in Sports Tunis, Tunisia, [2]BenficaLAB, Sport Lisboa e Benfica Sport Science Department, Lisbon, Portugal, [3]Inter-university Laboratory of Human Movement Biology, University Claude Bernard Lyon 1, University of Lyon, Lyon, France, [4]School of Public Health, Department of Health Sciences (DISSAL), University of Genoa, Genoa 16132, Italy, [5]Center of Rehabilitation for Disabled and Life-injured of Manouba, Tunisia, [6]Athlete Health and Performance Research Center, Qatar Orthopedic and Sports Medicine Hospital, Doha, Qatar

ABSTRACT

Background: Soccer players require a plethora of physical capabilities to compete at a higher level. It would be interesting to determine which physical attributes are required for starting players (SP, players chosen in the squad starting the games), and what sets them apart from non-starting players (NSP). **Aim:** 1) to compare physical attributes of SP vs. NSP, and 2) to determine if strength ratios calculated from maximal isometric strength (MIVC) is useful to differentiate between two different groupsof players. **Methods:** Thirty U17 right-leg dominant elite youth soccer players were divided in two groups (starters players [SP; N=15] and non-starters players [SP; N=15]. All players performed a battery of tests: 10m straight-sprint (10 m SS), change of direction (COD), maximal isometric voluntary contraction (MIVC), jumping and dynamic-balance tests. Hamstring to quadriceps ratios (H: Q) and side to side asymmetry werealso calculated from MIVC tests. **Results:** Comparison results showed that SP didbetter in jumping tests (five-jump test [5JT] and broad jump test[BJT] compared to NSP. SP were also able to exert more isometric strength when compared to NSP. SP were faster and presented a better COD ability than NSP. However,no significant differences between the two groups in dynamic-balance ability. Agreater H: Q asymmetry was observedamong NSP compared to SP. **Conclusions:** Youth elite SP's may be distinguished from NSP's through higher isometric strength, jumping, speed and COD tests. Thus, coaches can use theses field tests for designing specific training programs for substitute players to reach a higher level of soccer play.

Keywords: Ratios, soccer, isometric strength, balance, change of direction

INTRODUCTION

In order to perform at high-level within professional elite soccer, it is important that players have adequate lower body strength, linear sprint ability and the capacity to perform explosive, quick change of direction (COD) movements.[1] These key physical capabilities make up the profile of the modern successful soccer players.[29] Recent research suggest how duringsoccer match-play, elite professional players perform more than 220 high-speed runs[21] withapproximately 720 CODswithboth the left and right side.[3] Furthermore, it has been reported that dynamicbalance ability is primordial in order to avoid imbalance since soccer actions are oftenperformed unilaterally (i.e. kicking, jumping and crossing).[10] When discussing the physical

Access this article online

Website: http://sjsr.se/

ISSN: 2001-9211

Address for correspondence:
Mehdi Rouissi, Tunisian Research Laboratory "Sports Performance Optimization" National Center of Medicine and Sciences in Sports (CNMSS), Bp 263, Ave Med Ali Akid, 1004 El Menzah, Tunis, Tunisia. Tel: (+216) 53 56 83 46, E-mail: mehdirwissi@gmail.com

qualities of soccer players across many levels of play, a greaterrate of lower limb muscle strength and power is required to perform high speed, explosive and decisive match actions (i.e. jumping, talking and sprinting).[13,35] For example, the quadriceps musclesare utilizedconcentrically when passing, kicking or jumping, whereas, hamstring muscles are eccentrically usedwhen performing decelerations and CODs but work concentrically in sprintactions.[22,24] consequently, imbalances between these two muscle groups may lead to an increased risk of hamstring and/or anterior cruciate ligament (ACL) injuries.[32] Hamstring to quadriceps (H: Q) and side to side asymmetry ratios are often screened to determine strength asymmetries.[4] These ratios are subsequently calculated via maximal isokinetic assessment via laboratory dynamometers which are generally of limited access.[6] Subsequently, the use of handheld dynamometers (HHD) may be proposed asa solution for a filed use. To date however, no studies regarding the usefulness of maximal isometric strength replacing the useof isokinetic strength in order to calculate strength ratios have been reported.

In order to determine the physical characteristics of soccer players, many researchers have described use of video analysis and computer software programs,[12] however, many studies compared the fitness performance of high level players to sub-elite population.[14,16,20,23] For example, Gabbett, et al.[14] has recently compared speed, COD capacity and reactive agility between elite vs. sub-elite rugby league players. It was revealed that elite players had superior sprint qualities and quicker decision reactive timesvs. sub-elite players. In addition, Mohamed, et al.[20] utilized the*EUROFIT*battery and specific fitness assessment tests to compare between elite and sub-elite youth handball players. Findings highlighted how elite players scored significantly better on strength, speed and agility but no difference was shown with balance capability.

Specifically within soccer, recent literature has provided analysis concerning the strength and speed characteristics of elite, sub-elite and recreational youth players.[16] Results have shown that the elite group presented significantly higher isometric strength, vertical jump height and short-sprint performancesin comparison with sub-elite groups.This is in-line with similar studies reporting greater strength and strength ratios in elite soccer players compared to sub-elite players.[6] As suggested by Young, et al.[36], care should be taken when comparing between elite vs. sub-elite players especially when the level of play between players is substantial. In this case, differences are likely, and it may be tempting to overstate the importance of a fitness quality to achieve success at the elite level. In this context, in order to minimizethe effect of bias it is wise to compare physical qualities of players from the same squad.

The multi-skilled and multi-demanding physical aspect anddimension of elite soccer raises the question of what physical attributes differentiate between SP and NSP. This is of great significance when trying to improve physical qualities among substitute players. Responding to this question may provide both technical staff andindividuals involved with the physical preparation of players, greater insight into the physical demands placed on youth soccer players. To the authors' knowledge, no current studies have compared the physical qualities and strength ratios between SP vs. NSP of elite youth soccer players. Furthermore, there are no studies regarding the usefulness of strength ratios calculated from maximal isometric voluntary contraction using the handheld dynamometer instead of isokinetic strength. As a result, the aim of the present study was two-fold 1) to compare physical attributes of SP vs. NSP, and 2) to determinate if strength ratios calculated from MIVC is useful to compare between two different levels of players.

MATERIALS AND METHODS

Participants

Thirty (U17)elite youth soccer players selected from a large playing list of the same team participated in the study (table 1).

Players were selected based on six inclusion/exclusion criteria:

1- They were trained subjects.
2- Injured players who were unavailable for selection were excluded.

Table 1: Anthropometrical characteristics of SP vs. NSP

Variables	Starters (n=15)	Non-starters (n=15)
Age (y)	16.78±0.35	16.52±0.23
Height (cm)	173±4.2	174±3.5
Body mass (kg)	67.14±5.12	65.74±6.22
Leg-length (cm)	93.56±5.63	94.90±4.39

3- Goalkeepers were excluded from the study.
4- Only players who had between 16 and 17 years old at the beginning of the study were involved.
5- Players who performed an extra-training were excluded.
6- Selected players had had at least 5 years of soccer practice within the 1st Division of the national youth soccer league

Players were divided into two groups (starters vs. non-starters) according to their playing time, where Substitute players were chosen from those who played at least 10-min per game. All tests were administered during the competition phase (3rd month of the season), where their training schedule consisted of approximately five training sessions and one official game per-week. Before data collection, all participants were informed about the aim and the potential risks of the study. The study was conducted according to the declaration of Helsinki and the protocol was approved by the institutional ethics committee. All participants and their parents/guardians reviewed and signed written informed consents.

Design

Testing sessions were carried out on a 3rd generation synthetic soccer turf in the morning between 9 am and 11am, where the temperature and humidity were of 16°C and 70% respectively. To ensure a good adherence to the pitch, players were asked to wear adapted molded plastic soccer boots throughout the testing sessions. All players performed at least two familiarization sessions before starting with tests.During the 48 hours preceding testing, players refrained from heavy training and maintained their usual daily training (technical and tactical training). Before performing tests, 10-min of standardized warm-up, excluding static stretching was administered for all participants.Isometric strength tests were carried out in a clinical examination room by an experimented physiotherapist.

10 m Straight-Sprint Test (10 m SS)

The test consisted of sprinting as fast as possible over a distance of 10mas between the starting and the finishing lines. The test started with players positioned in a standing position with their preferred foot forward and behind the starting line. The total time was recorded using photocell gates (Brower Timing Systems, Salt Lake City, UT; accuracy of 0.01 s) with gates located at a height of 0.5 m from the ground and spaced by 1 m. The fastest timed sprint performance was used in the present study.

Jumping Tests

All players performed three jumping tests: 1) the 5JT which consisted of covering the greatest horizontal distance possible by achieving five alternate leg jumps. Players started and finished the test in a standing position with their feet parallel. A fixed measuring tape was used to measure the horizontal jumping performance (from the front part of the player's feet at the starting position to the rear part of the feet at the final landing position). The best 5JT performance was expressed relative to leg length and used for statistical analysis. 2) The triple hop-jump test consisted of performing three consecutive maximal horizontal jumps with the same leg and using an arm swing. Players started in a standing position on the designed testing leg, with their big toe on the starting line. The performance was measured with a fixed measuring tape from the starting line to rear edge of the heel after completing the third hop and the best performance was recorded for analysis. 3) The standing broad-jump test started with players in a standing position with their feet parallel and shoulder-width apart behind a starting line. The test consisted of jumping forward as far as possible with both feet simultaneously with the possibility of using an arm swing. The total performance was assessed from the starting line to the rear edge of the heel after completing the jump via a fixed measuring tape.

Modified Illinois Change of Direction Test

The MICODT were performed with players starting in a standing position, with their preferred foot forward and placed 0.5 m behind the starting line. The test involves players to sprint and changing direction as fast as possible from point A to point B as indicated in Figure 1. Test's performance was measured via two timing gates (Brower Timing Systems, Salt Lake City, UT; accuracy of 0.01 second) placed at the start and at the finish lines. The test were performed twice with three minutes of rest in between and the best performance (shortest time) was used for statistical analysis. During the test, participants did not receive any technical advice in relation with the technique of changing direction.

Maximal Isometric Voluntary Contraction Test

MIVC was measured using a valid and reliable portable dynamometer (Microfet 2, Hoggan Health Industries, Inc., Draper, UT).[9,11] Maximal isometric strength of the

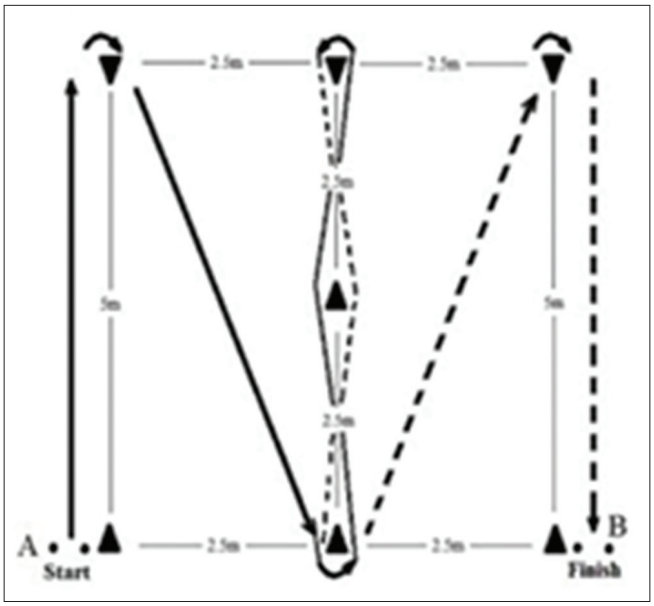


Figure 1: Diagram of the modified illinois change of direction test

knee flexors/extensors was measured twice on each side of the body. The test started when the examiner applied resistance in a fixed position and the player exerted 5 s of maximal isometric force against the dynamometer. The participants were told to stabilize themselves by holding on to the sides of the table with their hands. All MIVC test were performed according to procedures applied in clinical settings.[5,34] Maximal isometric strength was measured in a sitting position with the dynamometer placed on the posterior aspect of the calcaneus for the knee flexors and placed perpendicular to the anterior aspect of the tibia, 5 cm proximal of the medial malleolus for the knee extensors.[28] All tests were administered twice and the best performance (high value of strength) was recorded for analysis. Two minutes of rest were allowed between trials in order to avoid a decline of strength. Performance was assessed via a handheld dynamometer (Microfet 2, Hoggan Health Industries, Inc., Draper, UT) and has been expressed as absolute (N) and allometrically scaled ($N \cdot kg^{-0.67}$) values.[7]

Star Excursion Balance Test (SEBT)

Balance was investigated using the Star Excursion Balance Test (SEBT). SEBT assesses dynamic single leg balance while reaching in 8 reach directions based on the orientation of the stance limb: namely, anterior, posterior, medial, lateral, anterior lateral, anterior medial, posterior lateral, and posterior medial.[8] The SEBT is performed by placing strips of tape on the floor in a grid format while the participant stands in the middle of the grid and reaches as far as possible in one reach direction touching down lightly so the researcher can mark and subsequently measure the reached distance. Trials are considered successful when there is no movement in the stance limb during the SEBT, controlled motion while maintaining balance, and returning of the reaching limb back to the starting point.Sincereach distance is related to limblength, it was normalizedto limb length by dividing the reach distance by limb length then multiplied by 100.[27] In order to compare SP vs. NSP, a global index of balance was calculated (composite score). The composite score was the sum of eight reach distance divided by eight times limb length, and then multiplied by 100.[27]

Strength Ratios

Isometric strength ratios were calculated as calculated from maximal isokinetic strength.[32] The H:Q ratio was calculated by dividing the hamstrings isometric strength by Quadriceps isometric strength. The side to side strength asymmetry was calculated as follows: ((isometric strength of the stronger leg - isometric strength of the weaker leg)/isometric strength of the weaker leg)*100.

Statistical Analysis

Statistical analyses were performed using SPSS software statistical package (SPSS Inc., Chicago, IL, version. 18.0). All variables were shown as mean ± SD. Preliminary assumption testing was conducted to check for normality, linearity, and multicollinearity. Independent t-test (s) were used to compare physical tests between starter and non-starter players, and statistical significance was set at $p<0.05$.

Table 2: Isometric strength and lower limb power test of starter vs. non-starter players

Variable	SP	NSP	P -value
Relative 5JT (m)	2.46±0.20	2.33±0.14	0.04
THJ-DL (m)	6.20±0.68	6.10±0.44	0.54
THJ-NDL (m)	6.31±0.57	6.14±0.41	0.36
BJT (m)	2.22±0.14	2.12±0.12	0.03
Knee flexors DL ($N.kg^{-0.67}$)	16.89±3.08	14.92±1.92	0.04
Knee flexors NDL ($N.kg^{-0.67}$)	15.99±2.79	13.86±1.84	0.02
Knee extensors DL ($N.kg^{-0.67}$)	35.39±3.12	33.05±2.73	0.03
Knee extensors NDL ($N.kg^{-0.67}$)	31.60±4.77	32.23±4.03	0.70

SP: starter-players; NSP: non-starter players; 5JT: five-jump test; THJ: triple-hop jump; BJT: broad-jump test; DL: dominant leg; NDL: non-dominant leg

Table 3: Straight sprint, change of direction and balance tests of starter vs. non-starter players

Variable	SP	NSP	P -value
10 m SS (s)	1.79±0.07	1.86±0.08	0.03
MICODT (m)	11.57±0.46	12.07±0.51	0.007
SEBT			
Composite score with DL (%)	99.32±6.99	99.37±10.07	0.99
Composite score with NDL(%)	96.84±8.99	96.68±9.49	0.96

SS: straight-sprint; MICODT: modified Illinois change of direction test; SEBT: start excursion balance test

Table 4: Isometric lower limb strength ratios of starter vs. non-starter players

Variable	SP	NSP	P -value
H:Q isometric strength ratios			
Dominant leg	0.48±0.09	0.54±0.07	0.48
Non-dominant leg	0.51±0.11	0.44±0.08	0.04
Side to side asymmetry			
Hamstring (%)	5.98±9.90	8.06±9.04	0.55
Quadriceps (%)	7.54±12.81	3.28±8.10	0.28

H: hamstring; Q: Quadriceps.

RESULTS

Comparison results of explosive and isometric strength tests are summarized in table 2. Statistical analysis showed that SP's were better in 5JT and BJT tests when compared to NSP. However, no significant difference between SP and NSPin THJ tests with DL and NDL. Furthermore, the present study showed that SP's were able to exert more isometric strength (knee flexion and extension) with the DL and NDL when compared to NSP. There were no significant differences between the two groups in the SBET composite score. However, SP were faster (10mSS) and presented a better COD ability than NSP (table 3). Analysis of isometric strength ratios reveled greater H: Q asymmetry among NSP compared to SP (table 4).

DISCUSSION

The purpose of the present study was to compare a range of physical attributes between starters and non-starters eliteyouth soccer players with the aim of characterizing this population and highlight limiting performance measures. The novelty of this specific studywas the comparison between SP and NSP from the same squad. Results demonstrate that SP have better straight-sprint, change of direction, lower limb isometric strength and jump performance (relative 5JT) than NSP, suggesting that these physical qualities may contribute to the higher playing standard of elite young elite players.

The results of the present study were in accordance with previous studies performed in team sport. Indeed,Gabbett, et al.[15] reported that rugby SP had greater speed, COD and jump performance compared to NSP. Moreover,Young, et al.[36] showed that AFL SP presented better leg power and linear sprinting performance when compared to NSP. In the present study, the difference in speed, COD and jumping performance between SP and NSP highlight the importance of these physical attributes in a high level of soccer competition.

Soccer requires maintaining unilateral balance when executing movement with the contralateral leg (i.e. kicking, jumping, and crossing the ball).[31] It has been reported that dynamic balance requires standing whilst maintaining isometric posture of lower limb muscles. Chtara, et al.[10] reported a significant positive relationship between isometric strength (DL and NDL) and dynamic balance ability (y-balance test), whereas a stepwise multiple regression analysis of the study also showed that maximal isometric strength explained between 21.9% and 49.4% of the variance of the Y-balance test. Despite the importance of dynamic balance in soccer, the present study reported no significant difference in dynamic balance ability between SP vs. NSP. Thus indicates that balance ability is not a discriminative quality between two levels of players from the same squad. To our knowledge, this is the first study comparing balance ability of players from the same squad, and as a result it can be suggested that the non-significant difference in balance between SP and NSP may be explained by the similarities in term of training program (strength training) and training load between the two groups. Indeed, it has been indicated that professional soccer players had better balance ability compared to amateur players[25,26] due to the difference in the levels of expertise and the training program and intensity between professional and amateur players.

Isometric tests are used to assess the force-producing capacity of the neuromuscular system.[17] Lower limb isometric strength is often measured via the Biodex system dynamometer which provides a high reliability and represents the gold standard. However, this machine is very costly and not portable for a filed

use. Thus, the novel aspect of the present study is the comparison of isometric strength in SP vs. NSP young soccer players via a hand-held dynamometer. This dynamometer presents a good reliability and accurate assessment among young and adult soccer players.[34] In the present study, SP presented higher lower limb isometric strength compared to NSP (expect Knee extensors of NDL). The results of the present study could be considered similar to those reported by Gissis, et al.[16], indicating significant difference in lower limb isometric strength among three level of young soccer players. However, the present study were not in accordance with the findings of Young, et al.[36] whoreported no significant differencesamongstlower limb strength between SP vs. NSP. We speculate that this difference could be explained by the difference in the study design between the two studies. Indeed, in the present study, isometric lower limb strength has been measuredwith a handheld dynamometer. However, in the Young, et al.[36] study, it has been assessed by isokinetic dynamometry. Moreover, the present study has been conducted among young soccer players while the study of young et al among adult Australian football players. The differences in maximal isometric strength found between SP and NSP in the present study could be attributed to the fact that SP participate in a greater number of weekly soccer game in comparison with NSP, which allow them to perform a high number of high-intensity actions compared to NSP. Indeed, it has been suggested that players who are exposed to increased playing minutes as a result will generally improve their technical and physical capacity compared to players who are substitutes or are not exposed to increased playing time.[33] Unfortunately the training load has not been monitored in the present study. Moreover, lower limb isometric strength is highly related to performance. Indeed, it has been reported that the force produced during the first 100 ms is an important part of the isometric force–time curve because it is the initial development of force, and it represents the ability of the musculoskeletal system to rapidly develop maximal force.[16] Therefore, we speculate that a high level of isometric strength is necessary to reach a high level of play in soccer.

Linear sprinting ability and rapid changing direction are essential components of modern soccer and can distinguish between the levels of play (Elite vs. sub elite).[29] However, to our knowledge, this is the first study that aimed to compare these physical qualities in starters vs. non-starters young soccer players. The present study showed a better 10 m SS performance in SP compared to NSP. These results are consistent with those reported byYoung, et al.[36] who indicated that in AFL, SP had better sprint times than NSP. Moreover, Manson, et al.[19] reported that in female soccer players, SP tended to be faster than NSP. In the same context, the results of the present study indicated a better COD performance among SP compared to NSP.Gabbett, et al.[15] highlighted contrasting reports to the present studyindicating no significant difference in agility performance between starters and non-starters junior rugby players. The difference between our finding and those of Gabbett, et al.[15] may be due to the difference in the participants (rugby players vs. soccer players). Moreover, the COD test suggested by Gabbett, et al.[15] was different from theone used in the present study. Indeed, the 505 test is composed by only one COD of 180°, while the MICODT is composed by multiple cuts at angle less than 180°. It should be noted that having a high level of strength may enhance others motor skills such as jumping, sprinting or changing direction.[1] Thus the better agility and sprinting performance reported by the present study among SP vs.NSP could be explained partly by the significant difference in isometric strength between the two levels of players. Indeed, it has been reported that isometric strength of the lower-limb muscles represented a major determinant factor of sprinting and COD-ability.[30]

Jumping tests are used to assess lower-limb power, and commonly features when testing for talent identification in soccer.[18,29] It has been reported that the force developed by the lower limb extensors and intramuscular coordination and co-activation are the main factors affecting the jumping performance. In a team sports such as the soccer, a high level of power production represents an important factor of success.[2] The results of the current study demonstrated that SP had a better jumping performance (relative 5JT and BJT) than NSP. However, no significant differences in the THJ (DL and NDL) between the two levels of players. The results of the present study are in accordance with many studies. Indeed, Baker 1993 reported a higher vertical jump index among SP vs. NSP. Moreover, Young et al reported a better CMJ and DJ performance among AFL SP when compared to NSP. On the other hand, others studies reported no significant differences in jumping performance between SP vs. NSP from the same squad. For example, it has been reported that starter's junior rugby players had not higher jumping performance than NSP. The

difference between the previous study and our results may be explained by the difference in the design of the two studies. Indeed, power tests of the present study are composed by horizontal jumping tests (horizontal and vertical component), while Gabbett, et al.[15] used only a vertical jumping tests to assess lower limb power. Although that soccer players are characterized by a between-legs asymmetries due to unilateral use of the legs (jumping, kicking)[31], the present study showed that unilateral jumping tests (THJ with DL and NDL) did not differentiate between starters and non-starters players.

The assessment of lower limb strength output in soccer is important in order to detect any muscle imbalance. Isokinetic dynamometers are usually used in such context and represent the gold standard of strength measuring. It has been reported that Quadriceps and hamstring muscles are very involved in soccer and that any asymmetries between theses muscles groups increase the risk of injury occurrence. In order to screen for lower limb asymmetries hamstring to quadriceps (H:Q) and side to side asymmetry ratios are calculated via maximal isokinetic assessment through costly laboratory dynamometers which cannot be useful in the field. Despite the fact that previous studies showed that HHD is a reliable instrument and could replace isokinetic dynamometers for a field use, this is the first study that calculated strength ratios from maximal strength measure via a portable dynamometer. The authors of the present study believe that such design needs a scientific validation in a large sample; however, this study could be a pilot one for future investigations. The present study showed no significant difference in Side to side asymmetry ratios (hamstring and quadriceps) between SP vs. NSP. However, H:Q isometric strength ratio of the NDL revealed a lower value among NSP compared to SP indicating a high risk of lower limb injury in NSP. Indeed it has been reported that the lower the H:Q ratio the higher the risk of knee injury.

The main limitation of the present study was the not assessing of maximal aerobic performance via a field test. Also, measuring only maximal isometric strength and power of limbs may be the second limit of the present study. Future studies should take into consideration maximal strength (1RM) when comparing SP vs. NSP. Linear sprinting ability was measured only via a 10 m SS test while 20 m and 30 m sprinting ability are also determinant factors of success in soccer. Finally, futures investigations should perform such analysis in a higher number of participants in order to draw a more general conclusion.

Practical Application

The present study showed that strength, speed and change of direction abilities could differentiate between two levels of players from the same squad suggesting that these physical qualities may provide useful information for attaining high soccer level. Thus, coaches and physical trainers can use theses field tests for designing specific training programs for substitute players to reach a higher level of soccer play.

CONCLUSION

In conclusion, the findings of the present study suggest that youth elite SP'smay be distinguished from NSP'sthroughlower isometric strength measured by a handheld dynamometer, jumping, speed and COD capabilities. Furthermore, dynamic balance ability does not seem to be a discriminating factor of success in elite youth soccer.

REFERENCES

1. M. Barker, T. J. Wyatt, R. L. Johnson, M. H. Stone, H. S. O'Bryant, C. Poe, and M. Kent. Performance Factors, Psychological Assessment, Physical Characteristics, and Football Playing Ability. *Journal of Strength & Conditioning Research.* 7 (1993), 224-33.
2. J. Bencke, R. Damsgaard, A. Saekmose, P. Jorgensen, K. Jorgensen, and K. Klausen. Anaerobic Power and Muscle Strength Characteristics of 11 Years Old Elite and Non-Elite Boys and Girls from Gymnastics, Team Handball, Tennis and Swimming. *Scand J Med Sci Sports.* 12 (2002), 171-8.
3. J. Bloomfield, R. Polman, and P. O'Donoghue. Physical Demands of Different Positions in Fa Premier League Soccer. *J Sports Sci Med.* 6 (2007), 63-70.
4. S. R. Brown, M. Brughelli, P. C. Griffiths, and J. B. Cronin. Lower-Extremity Isokinetic Strength Profiling in Professional Rugby League and Rugby Union. *Int J Sports Physiol Perform.* 9 (2014), 358-61.
5. M. Carroll, W. Joyce, A. Brenton-Rule, N. Dalbeth, and K. Rome. Assessment of Foot and Ankle Muscle Strength Using Hand Held Dynamometry in Patients with Established Rheumatoid Arthritis. *J Foot Ankle Res.* 6 (2013), 10.
6. A. Carvalho, S. Brown, and E. Abade. Evaluating Injury Risk in First and Second League Professional Portuguese Soccer: Muscular Strength and Asymmetry. *J Hum Kinet.* 51 (2016), 19-26.
7. K. Chamari, Y. Hachana, Y. B. Ahmed, O. Galy, F. Sghaier, J. C. Chatard, O. Hue, and U. Wisloff. Field and Laboratory Testing in Young Elite Soccer Players. *Br J Sports Med.* 38 (2004), 191-6.
8. N. J. Chimera, and M. Warren. Use of Clinical Movement Screening Tests to Predict Injury in Sport. *World J Orthop.* 7 (2016), 202-17.
9. S. P. Chrisman, J. W. O'Kane, N. L. Polissar, A. F. Tencer, C. D. Mack, M. R. Levy, and M. A. Schiff. Strength and Jump Biomechanics of Elite and Recreational Female Youth Soccer Players. *J Athl Train.* 47 (2012), 609-15.

10. M. Chtara, M. Rouissi, N. L. Bragazzi, A. L. Owen, M. Haddad, and K. Chamari. Dynamic Balance Ability in Young Elite Soccer Players: Implication of Isometric Strength. *J Sports Med Phys Fitness.* (2016).
11. J. F. Crow, A. J. Pearce, J. P. Veale, D. VanderWesthuizen, P. T. Coburn, and T. Pizzari. Hip Adductor Muscle Strength Is Reduced Preceding and During the Onset of Groin Pain in Elite Junior Australian Football Players. *J Sci Med Sport.* 13 (2010), 202-4.
12. B. Dawson, R. Hopkinson, B. Appleby, G. Stewart, and C. Roberts. Player Movement Patterns and Game Activities in the Australian Football League. *J Sci Med Sport.* 7 (2004), 278-91.
13. N. Eniseler, C. Sahan, H. Vurgun, and H. F. Mavi. Isokinetic Strength Responses to Season-Long Training and Competition in Turkish Elite Soccer Players. *J Hum Kinet.* 31 (2012), 159-68.
14. T. J. Gabbett, J. N. Kelly, and J. M. Sheppard. Speed, Change of Direction Speed, and Reactive Agility of Rugby League Players. *J Strength Cond Res.* 22 (2008), 174-81.
15. T. Gabbett, J. Kelly, S. Ralph, and D. Driscoll. Physiological and Anthropometric Characteristics of Junior Elite and Sub-Elite Rugby League Players, with Special Reference to Starters and Non-Starters. *J Sci Med Sport.* 12 (2009), 215-22.
16. I. Gissis, C. Papadopoulos, V. I. Kalapotharakos, A. Sotiropoulos, G. Komsis, and E. Manolopoulos. Strength and Speed Characteristics of Elite, Subelite, and Recreational Young Soccer Players. *Res Sports Med.* 14 (2006), 205-14.
17. K. Hakkinen. Neuromuscular Fatigue and Recovery in Male and Female Athletes During Heavy Resistance Exercise. *Int J Sports Med.* 14 (1993), 53-9.
18. F. le Gall, C. Carling, M. Williams, and T. Reilly. Anthropometric and Fitness Characteristics of International, Professional and Amateur Male Graduate Soccer Players from an Elite Youth Academy. *J Sci Med Sport.* 13 (2010), 90-5.
19. S. A. Manson, M. Brughelli, and N. K. Harris. Physiological Characteristics of International Female Soccer Players. *J Strength Cond Res.* 28 (2014), 308-18.
20. H. Mohamed, R. Vaeyens, S. Matthys, M. Multael, J. Lefevre, M. Lenoir, and R. Philppaerts. Anthropometric and Performance Measures for the Development of a Talent Detection and Identification Model in Youth Handball. *J Sports Sci.* 27 (2009), 257-66.
21. M. Mohr, P. Krustrup, and J. Bangsbo. Match Performance of High-Standard Soccer Players with Special Reference to Development of Fatigue. *J Sports Sci.* 21 (2003), 519-28.
22. R. R. Neptune, I. C. Wright, and A. J. van den Bogert. Muscle Coordination and Function During Cutting Movements. *Med Sci Sports Exerc.* 31 (1999), 294-302.
23. C. H. Ooi, A. Tan, A. Ahmad, K. W. Kwong, R. Sompong, K. A. Ghazali, S. L. Liew, W. J. Chai, and M. W. Thompson. Physiological Characteristics of Elite and Sub-Elite Badminton Players. *J Sports Sci.* 27 (2009), 1591-9.
24. D. A. Opar, and B. G. Serpell. Is There a Potential Relationship between Prior Hamstring Strain Injury and Increased Risk for Future Anterior Cruciate Ligament Injury? *Arch Phys Med Rehabil.* 95 (2014), 401-5.
25. T. Paillard, and F. Noe. Effect of Expertise and Visual Contribution on Postural Control in Soccer. *Scand J Med Sci Sports.* 16 (2006), 345-8.
26. T. Paillard, F. Noe, T. Riviere, V. Marion, R. Montoya, and P. Dupui. Postural Performance and Strategy in the Unipedal Stance of Soccer Players at Different Levels of Competition. *J Athl Train.* 41 (2006), 172-6.
27. P. J. Plisky, P. P. Gorman, R. J. Butler, K. B. Kiesel, F. B. Underwood, and B. Elkins. The Reliability of an Instrumented Device for Measuring Components of the Star Excursion Balance Test. *N Am J Sports Phys Ther.* 4 (2009), 92-9.
28. Y. H. Pua, T. V. Wrigley, S. M. Cowan, and K. L. Bennell. Intrarater Test-Retest Reliability of Hip Range of Motion and Hip Muscle Strength Measurements in Persons with Hip Osteoarthritis. *Arch Phys Med Rehabil.* 89 (2008), 1146-54.
29. T. Reilly, J. Bangsbo, and A. Franks. Anthropometric and Physiological Predispositions for Elite Soccer. *J Sports Sci.* 18 (2000), 669-83.
30. M. Rouissi, M. Chtara, A. Owen, A. Burnett, and K. Chamari. Change of Direction Ability in Young Elite Soccer Players: Determining Factors Vary with Angle Variation. *J Sports Med Phys Fitness.* (2016).
31. M. Rouissi, M. Chtara, A. Owen, A. Chaalali, A. Chaouachi, T. Gabbett, and K. Chamari. Effect of Leg Dominance on Change of Direction Ability Amongst Young Elite Soccer Players. *J Sports Sci.* 34 (2016), 542-8.
32. C. V. Ruas, F. Minozzo, M. D. Pinto, L. E. Brown, and R. S. Pinto. Lower-Extremity Strength Ratios of Professional Soccer Players According to Field Position. *J Strength Cond Res.* 29 (2015), 1220-6.
33. J. R. Silva, J. F. Magalhaes, A. A. Ascensao, E. M. Oliveira, A. F. Seabra, and A. N. Rebelo. Individual Match Playing Time During the Season Affects Fitness-Related Parameters of Male Professional Soccer Players. *J Strength Cond Res.* 25 (2011), 2729-39.
34. K. Thorborg, C. Couppe, J. Petersen, S. P. Magnusson, and P. Holmich. Eccentric Hip Adduction and Abduction Strength in Elite Soccer Players and Matched Controls: A Cross-Sectional Study. *Br J Sports Med.* 45 (2011), 10-3.
35. U. Wisloff, C. Castagna, J. Helgerud, R. Jones, and J. Hoff. Strong Correlation of Maximal Squat Strength with Sprint Performance and Vertical Jump Height in Elite Soccer Players. *Br J Sports Med.* 38 (2004), 285-8.
36. W. B. Young, R. U. Newton, T. L. Doyle, D. Chapman, S. Cormack, G. Stewart, and B. Dawson. Physiological and Anthropometric Characteristics of Starters and Non-Starters and Playing Positions in Elite Australian Rules Football: A Case Study. *J Sci Med Sport.* 8 (2005), 333-45.

The Swedish Journal of Scientific Research

Case Study

Changes Neuromuscular and Functional Performance of Elderly After Velocity-based Resistance Training

Ewertton de Souza Bezerra[1]*, Suzy Pinto[2], Tiago Nogueira[1], Leonardo Mendes[1], Aluísio Avelino[1], Inês A. Streit[1], Abderraouf Ben Abderrahman[2]

[1]Federal University of Amazonas, Brazil, [2]Higher Institute of Sport and Physical Education of Ksar-Said, Tunisia

ABSTRACT

The aim of this study was to investigate whether 24 sessions of velocity based training (VBT) exercise could changes the neuromuscular and functional performance in the elderly women. Six elderly participants (65 ± 5 years; 1,51 ± 0,05 m; 64 ±16 kg) were submitted to a progressive VBT regime (two sessions/week) using a squat jump barbell exercise. Time up and go (ES 0.86, large; p=0.01), squat jump (ES 0.71, moderate; p=0,03), squat jump barbell (ES 1.37, large; p=0,03), and dynamic knee extension (ES 0.54, moderate, p=0,04) were statistical different within period (POST better than PRE). On the other hand, results isometric knee extension (ES 0.12, small, p=0,58) and dynamic knee flexion (ES 0.08, small, p=0,72) did not show changes after the experimental period. In summary, the results of this study suggested that 24 sessions of VBT exercise influenced the functional performance (TUG); squat jump height and load of the barbell squat jumps; fast concentric knee extensor (180o/s), but not the flexion concentric (180o/s) and isometric knee extensor torques in a group of elderly women.

Keywords: Power training, aging, isokinetic

INTRODUCTION

The aging process is characterized by physiological and functional changes in the different systems of the human body. These changes appear in different progressions, and mainly affect the functions of the muscular systems. Within the more affects structure are: i) at the level of the motor neuron, there is the loss of motor units, neuronal atrophy and the reduction of the velocity conduction of the action potential; ii) at the level of the neuromuscular junction (synapse), the transmission of the neuromuscular response is slowed down; and iii) at the level of the muscle fibers, the reduction in the number and the size of the fibers characterize the muscular atrophy in the elderly people (1). Indeed, these alterations can explain the progressive decline of the physical functions (strength, flexibility, muscular and cardiorespiratory endurance), and neurological (coordination, balance), that can lead to functional consequences such as loss of autonomy and increased risk of falls and fractures (2,3).

Access this article online

Website: http://sjsr.se/

ISSN: 2001-9211

However, these deleterious physiologic effects of aging could be attenuate and even reverse by hormone therapy, nutritional strategies and physical activities. For the latter, there are two types: endurance training, which is based on the development of maximal aerobic power (VO2max) and resistance training (RT), which is based on the development of muscle

Address for correspondence:
Ewertton de Souza Bezerra, Av. General Rodrigo Octavio Jordão Ramos, 1200 - Coroado I, Manaus - AM, Brazil.
Zip code: 69067-005; E-mail: ewertton_bezerra@ufam.edu.br

functions (strength, power and muscular endurance). The currently literature has shown that TR allows to increase the surface of muscle fibers (hypertrophy), muscular protein synthesis, maximum muscle strength and power (1). Two regimes of training are used to develop muscular functions: i) high intensity training whose prescribed loads are equal to or greater than 85% of 1 maximum repetition (1-RM) and ii) the power training whose charges are prescribed between 30 to 60% of 1-RM. The study conducted by Correa et al. (4) showed that these two regimes of training are the most effective for the development of strength and muscular power. Traditionally, RT prescription is based on the maximum percentage of 1-RM, what frequently it requires a lot of time and periodic reevaluation in order to adapt the training load(5,6).

In this regard, the velocity-based training (VBT) arises as an alternative method, because the prescription is based on the velocity of load travel, for example, for power, (30 -60% 1RM) the prescribed velocity would be 0.8-1.3 m/s (7). In addition, adjusting the load in real time, to maintain the target velocity, can guarantee a better optimization of the training. However, to date this hypothesis was valued just sports studies (5,8). Conversely, no study has referred to the effects of the VBT program on the muscular functions of the elderly. Thus, our aim was evaluate the effects of VBT program on neuromuscular and functional performance of elderly women.

METHOD

Participants

Six female elderly over 60 years (65 ± 5 years; 1,51 ± 0,05 m; 64±16 kg) participated in the present case study. Participants were free from existing lower limb musculoskeletal disorders, and had no fractures or orthopaedic surgery in the last 5 years. All subjects signed an informed consent form and the Ethics Committee of Human Research approved the procedures (approval number: 3.139.675), in agreement with the Declaration of Helsinki (as 64th WMA General Assembly, Fortaleza, Brazil, October 2013).

Materials and Procedures

The vertical jump test was performed with an App my jump2® connect to iOS plataform (9). Participants performed 3 trials of squat jump (SJ) movement. During the SJ, the following command "squat", wait (3s) and "jump" were performed followed by the maximum vertical jump, the knee flexion was self selected. Both hands were kept positioned on the hips during the entire movement and legs were maintained in full extension during the flight phase. The interval between each jump was 60s. SJ height value was analysed. The best of the three attempts was adopted for analysis.

Muscular torque of the preferred limb was assessed via knee extension maximum voluntary isometric contraction and during on extension and flexion knee dynamic contraction (180º/s) an isokinetic dynamometer (Biodex® System 4, Biodex Medical Systems, Shirley, NY, USA). Participants were positioned in the dynamometer and the evaluated limb as well as the torso and pelvic region were stabilized using non-elastic straps to avoid compensatory movements. The seat was positioned at 85º of hip flexion and 70º of knee flexion (0º hip in neutral position and knee full extension). Subjects were instructed to produce force "as fast and hard as possible," with emphasis placed on a fast initiation of contraction. Verbal encouragement was given before and throughout the test. After positioning, an isokinetic warm-up was performed with 10 repetitions of concentric knee extension-flexion contractions at a range of motion from 20º to 100º and an angular velocity of 120º/s^{-1}(10).

Time up and go was recorded using a digital camera at a sampling frequency of 52 Hz (Sony®, model W800 New York City, New York,USA) and timed offline by an evaluator with specialized software (Kinovea®, France). The trial with the lowest completion time was used for further analysis. These procedures have been proposed to reduce measurement errors (11). Participants completed three trials with 30 seconds rest between attempts. The TUG test consisted of measuring the time needed to rise from a seated position, walk forward, and then return 2.44-m to a seated position as quickly as possible. The trial with lowest performance time was adopted for analysis(11).

The procedures to obtain the load which the subjects executed jump squat exercise on a free barbell between 0.75 and 0.9 m/s followed recommendations of Loturco et al.(12); barbell velocity was control by accelerometer (Push Training® 1.0, Toronto, CA)(13). Subjects were instructed to execute 3 trials at maximal velocity for each load, starting at 10% of their body mass. Participants executed a knee flexion until the thigh was parallel to the ground and, after an initial command, jumped as

fast as possible. Prior to each muscle power assessment, an experienced test administrator instructed the participant to maintain constant downward pressure on the barbell throughout the jump, to prevent the bar moving independently of the body. A load of 10% of body mass was gradually added in each set until the velocity target was achieved. This was observed after, on average, 5–6 sets. A 5-minute interval was provided between sets. A blinded researcher performed all tests.

Training Program

The velocity-based resistance training (VBT) program consisted of the exercise squat with barbell (4 sets X 6 repetitions) with 2 minutes of interval between sets. The displacement velocity in the concentric phase was controlled by the accelerometer (Push Band 1.0), which is always maintained between 0.75 and 0.90 m/s. Previously the sessions were performed a specific warm-up (core and joint mobility), as well as, the bench press exercise was used to complementary the training session. There was increment (minimum of 10%) and/or maintenance of the load (reevaluations were done every four sessions).

Statistical Analysis

All values are reported as mean ± SD. Normality of distribution and homoscedasticity for outcome measures were tested using the Shapiro-Wilk test and Levene's criterion, respectively. Dependent student t-test was applied to analyze the differences within group after the experimental period. An alpha level of $p \leq 0.05$ was used to determine statistical significance The first part of statistical procedure was performed using SPSS 21 for windows (Statistical Package for the Social Science, IBM, Chicago, Ill, USA). Complementary analysis applied for practical significance using magnitude-based inferences was executed. The smallest worthwhile change (0.2 x between-subjects

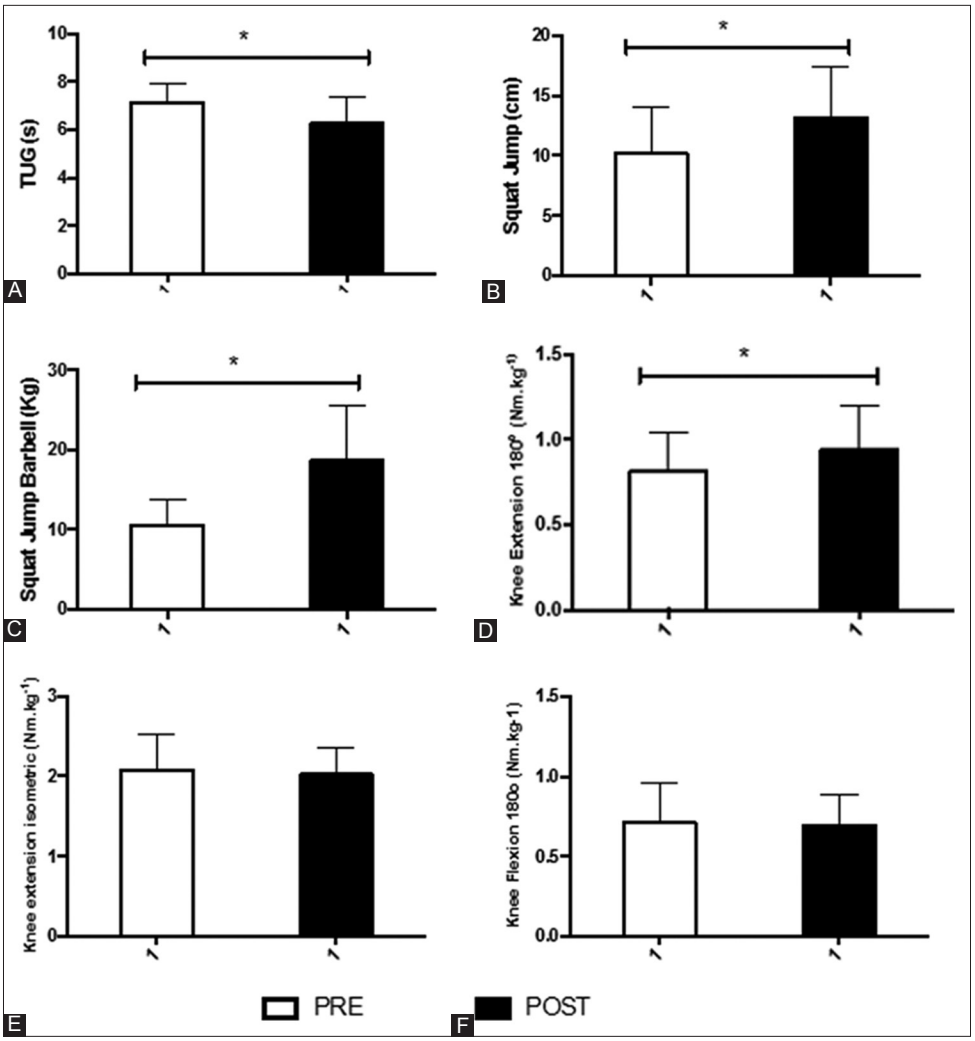


Figure 1: (A-F) Inferential analysis comparing measures in two different periods (PRE vs. POST),* statistical difference to PRE

standard deviation SD) and 90% confidence intervals (CI) were determined for between-trial comparisons (i.e., PRE vs POST time) (14). The quantitative chances of higher/beneficial, trivial/similar, or lower/harmful differences were evaluated qualitatively as follows: <1%, *almost certainly not*; 1% to 5%, *very unlikely*; 5% to 25%, *unlikely*; 25% to 75%, *possible*; 75% to 95%, *likely*; 95% to 99%, *very likely*; >99%, *almost certainly*(15). The true difference was assessed as unclear when the chances of having positive and negative results were both >5%. Threshold values for Cohen's effect size (ES)(16) statistics were >0.2 (small), >0.5 (moderate), and >0.8 (large).

RESULTS

Time up and go (ES 0.86, large; p=0.01), squat jump (ES 0.71, moderate; p=0,03), squat jump barbell (ES 1.37, large; p=0,03), and dynamic knee extension (ES 0.54, moderate, p=0,04) were statistical different within period (POST better than PRE), figure 1A to 1D, respectively. On the other hand, results isometric knee extension (ES 0.12, small, p=0,58) and dynamic knee flexion (ES 0.08, small, p=0,72) did not show changes after the experimental period, figure 1E and 1F, respectively.

The effect size and quantitative changes values of all variables analyzed are report in figure 2. Compared with the baseline, the post training report *likely* to TUG, SJ, SJ Barbell, and *possible to* knee extension 180º/s. On the other hand, isometric knee extension and flex knee extension 180º/s report *unclear*.

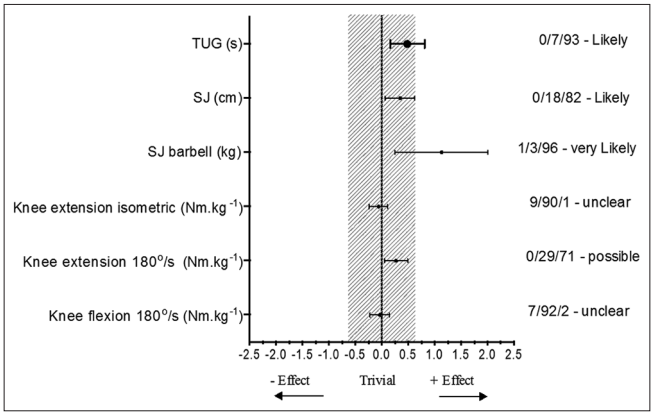


Figure 2: Post-intervention changes to post intervention regarding to baseline on neuromuscular and functional performance (expressed as standardized mean difference). Bars indicate uncertainty in the true mean changes with 90% confidence intervals. Trivial area was calculated from the smallest worthwhile change (see methods). Note - SJ: squat jump

DISCUSSION AND CONCLUSION

The main findings of the case study were that application of VBT with squat jump barbell (4 sets x 6 repetitions with 0,75 to 0,9 m/s) resulted in a decrease on time executed of time up and go test, as well as, improve on squat jump height, muscular knee extension torque with 180º/s, and load travelled during the squat a jump with barbell. However, no changes between two periods were observed for muscular knee flexion torque with 180º/s and isometric knee extension. The results confirming our initial hypothesis that VBT is able to improve neuromuscular and functional performance in elderly people.

Regarding the time up and go, an interesting finding was that the application of VBT was enough to increase performance. Some studies related changes after power training in functional performance (17,18), and it apparently occur with minimal session include on the RT program. Sakugawa et al. (19) showed decrease on time response for TUG after 16 sessions, within which only 4 sessions were performed with high speed; similarly Bezerra et al. (20) verified a significant reduction in TUG performance after 27 workouts of RT, the detail was that independent of periodization model (traditional or mixed session) both groups performance 27 sets with high speed during the concentric phase in two exercises (leg press and seated leg curl). Our current data present a likely magnitude-based inferences to TUG (see figure 1), the difference with the studies mentioned above was in the present protocol we control the velocity between 0,7 and 0,9 m/s, what according of force-velocity relationship the maximum power peak is found (21).

Squat jump height and load of the barbell squat jump results converge with similar TUG responses after intervention. Previous studies report increase in power jump height in the elderly (≅ 37%) after sessions with sets executed with high-velocity contractions (30–50% of 1RM) as part of a traditional heavy RT program (22,23) or training only with fast concentric contractions (24). The improvement in power performance might be associated with maintenance of fast-twitch muscle fibers, and an increase in maximal fiber contraction velocity in elderly people (21).

Our results showed that a short-term training program significantly increased the concentric peak torque 180º/s after 24 sessions of the VBT exercise. The findings of

the current study are in agreement with previous studies (25) showing that strength training may result in neural and morphological adaptations that maintain or increase the strength production capacity even in elderly individuals. Our particular stimulus difference compared with others studies (19,23,26), it is while these studies applied percentage of one maximum repetition, we controlled the load with accelerometer what permit us constant adjust of it. This particular way of load control already applied with sports studies (5,8). However, to the best our knowledge it was the first study of applied in elderly people, our specific result in high velocity during isokinetic evaluate has direct connect with the velocity control during the exercise execute, maybe for this we did not observe changes in concentric knee flex during 180º/s and isometric contraction. Furthermore, it was possible that did not occur a complete adaptation in lower limb, as it observed to Orssatto et al. (27) after 12 weeks of RT applied just de leg press 45º, as the previous study we should considerate the specific adaptations caused by exercise and velocity of the load.

The present case study is inherent in limitations. First, our limited sample was justified for being a exploratory idea, while we know that is a limiter factor, however our data showed for a inference analyses to compare baseline to post intervention is necessary minimal of 30 subjects (G*Power Statistical Program, effect size: 0,71; Power (1-β err prob): 0.95; and α err prob:0.05). Second, these results are restricted to this population (range 60 and 70 years old) and training protocol; extrapolation for other conditions should be made with caution. In summary, the results of this study suggested that 24 sessions of VBT exercise influenced the functional performance (TUG); squat jump height and load of the barbell squat jumps; fast concentric knee extensor (180º/s), but not the flexion concentric (180º/s) and isometric knee extensor torques in a group of elderly women.

REFERENCES

1. Hunter SK, Pereira HM, Keenan KG. The aging neuromuscular system and motor performance. Journal of Applied Physiologyhysiology (Bethesda, Md : 1985) [Internet]. American Physiological Society; 2016 [cited 2018 Dec 8];121(4):982–95. Available from: http://www.ncbi.nlm.nih.gov/pubmed/27516536
2. Clark BC, Manini TM. Functional consequences of sarcopenia and dynapenia in the elderly. Curr Opin Clin Nutr Metab Care [Internet]. 2010;13(3):271–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20154609
3. Trombetti A, Reid KF, Hars M, Herrmann FR, Pasha E, Phillips EM, et al. Age-associated declines in muscle mass, strength, power, and physical performance: impact on fear of falling and quality of life. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA [Internet]. NIH Public Access; 2016 Feb [cited 2019 Feb 19];27(2):463–71. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26194491
4. Correa C, LaRoche D, Cadore E, Reischak-Oliveira a., Bottaro M, Kruel LF, et al. 3 Different Types of Strength Training in Older Women. International Journal of Sports Medicine. 2012;962–9.
5. Rauch JT, Loturco I, Cheesman N, Thiel J, Alvarez M, Miller N, et al. Similar Strength and Power Adaptations between Two Different Velocity-Based Training Regimens in Collegiate Female Volleyball Players. Sports (Basel, Switzerland) [Internet]. Multidisciplinary Digital Publishing Institute (MDPI); 2018 Dec 4 [cited 2019 Feb 19];6(4). Available from: http://www.ncbi.nlm.nih.gov/pubmed/30518071
6. Banyard HG, Tufano JJ, Delgado J, Thompson SW, Nosaka K. Comparison of the Effects of Velocity-Based Training Methods and Traditional 1RM-Percent-Based Training Prescription on Acute Kinetic and Kinematic Variables. International journal of sports physiology and performance [Internet]. 2019 Feb 1 [cited 2019 Feb 19];14(2):246–55. Available from: https://journals.humankinetics.com/doi/10.1123/ijspp.2018-0147
7. González-Badillo JJ, Sánchez-Medina L. Movement Velocity as a Measure of Loading Intensity in Resistance Training. International Journal of Sports Medicine [Internet]. 2010 May 23 [cited 2019 Feb 19];31(05):347–52. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20180176
8. Loturco I, Nakamura FY, Kobal R, Gil S, Pivetti B, Pereira LA, et al. Traditional Periodization versus Optimum Training Load Applied to Soccer Players: Effects on Neuromuscular Abilities. International Journal of Sports Medicine. 2016;37(13):1051–9.
9. Cruvinel-Cabral RM, Oliveira-Silva I, Medeiros AR, Claudino JG, Jiménez-Reyes P, Boullosa DA. The validity and reliability of the "My Jump App" for measuring jump height of the elderly. PeerJ [Internet]. PeerJ, Inc; 2018 [cited 2019 Feb 19];6:e5804. Available from: http://www.ncbi.nlm.nih.gov/pubmed/30356977
10. da Rosa Orssatto LB, de Moura BM, de Souza Bezerra E, Andersen LL, de Oliveira SN, Diefenthaeler F. Influence of strength training intensity on subsequent recovery in elderly. Experimental gerontology [Internet]. Elsevier; 2018;106(March):232–9. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0531556517309087%0Ahttp://www.ncbi.nlm.nih.gov/pubmed/29540305
11. Silva ME da, Orssatto LB da R, Bezerra E de S, Silva DAS, Moura BM de, Diefenthaeler F, et al. Reducing measurement errors during functional capacity tests in elders. Aging Clinical and Experimental Research. Springer International Publishing; 2017;In Press(0):0.
12. Loturco I, Nakamura FY, Tricoli V, Kobal R, Abad CCC, Kitamura K, et al. Determining the optimum power load in jump squat using the mean propulsive velocity. PLoS ONE. 2015; 10(10):1–12.
13. Balsalobre-Fernández C, Kuzdub M, Poveda-Ortiz P, Campo-Vecino J Del. Validity and Reliability of the PUSH Wearable Device to Measure Movement Velocity During the Back Squat Exercise. Journal of strength and conditioning research [Internet]. 2016 Jul [cited 2019 Feb 19];30(7):1968–74. Available from: https://insights.ovid.com/crossref?an=00124278-201607000-00021
14. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Medicine and Science in Sports and Exercise. 2009;41(1):3–12.
15. Hopkins WG. Measures of Reliability in Sports Medicine and Science. Sports Medicine [Internet]. 2000 Jul [cited 2018 Nov 7];30(1):1–15. Available from: http://www.ncbi.nlm.nih.gov/pubmed/10907753
16. Cohen J. Statistical power analysis for the behavioral sciences. L.

Erlbaum Associates; 1988. 567 p.

17. Cadore EL, Casas-Herrero A, Zambom-Ferraresi F, Idoate F, Millor N, Gómez M, et al. Multicomponent exercises including muscle power training enhance muscle mass, power output, and functional outcomes in institutionalized frail nonagenarians. AGE [Internet]. 2014 Apr 13;36(2):773–85. Available from: http://link.springer.com/10.1007/s11357-013-9586-z
18. Cadore EL, Moneo ABB, Mensat MM, Muñoz AR, Casas-Herrero A, Rodriguez-Mañas L, et al. Positive effects of resistance training in frail elderly patients with dementia after long-term physical restraint. Age (Dordrecht, Netherlands) [Internet]. Springer; 2014 Apr [cited 2019 Feb 19];36(2):801–11. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24243397
19. Sakugawa RL, Moura BM, Orssatto LBDR, Bezerra EDS, Cadore EL, Diefenthaeler F. Effects of resistance training, detraining, and retraining on strength and functional capacity in elderly. Aging clinical and experimental research [Internet]. Springer International Publishing; 2018 May 17;1–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/29777475
20. Bezerra E de S, Orssatto LB da R, de Moura BM, Willardson JM, Simão R, Moro ARP. Mixed Session Periodization as a New Approach for Strength, Power, Functional Performance, and Body Composition Enhancement in Aging Adults. Journal of strength and conditioning research [Internet]. 2018 Oct;32(10):2795–806. Available from: http://www.ncbi.nlm.nih.gov/pubmed/30052598
21. Raj IS, Bird SR, Shield AJ. Aging and the force–velocity relationship of muscles. Experimental Gerontology [Internet]. 2010 Feb [cited 2018 Dec 8];45(2):81–90. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19883746
22. Izquierdo M, Häkkinen K, Ibañez J, Garrues M, Antón A, Zúñiga A, et al. Effects of strength training on muscle power and serum hormones in middle-aged and older men. Journal of Applied Physiology [Internet]. American Physiological SocietyBethesda, MD; 2001 Apr [cited 2019 Feb 19];90(4):1497–507. Available from: http://www.physiology.org/doi/10.1152/jappl.2001.90.4.1497
23. Bezerra E de S, Orssatto LB da R, de Moura BM, Willardson JM, Simão R, Moro ARP. Mixed Session Periodization as a New Approach for Strength, Power, Functional Performance, and Body Composition Enhancement in Aging Adults. Journal of Strength and Conditioning Research [Internet]. 2018 Jul 26 [cited 2018 Aug 20];1. Available from: http://www.ncbi.nlm.nih.gov/pubmed/30052598
24. Pereira A, Costa AM, Leitão JC, Monteiro AM, Izquierdo M, Silva AJ, et al. The influence of ACE ID and ACTN3 R577X polymorphisms on lower-extremity function in older women in response to high-speed power training. BMC geriatrics [Internet]. 2013;13:131. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=4029788&tool=pmcentrez&rendertype=abstract
25. Arnold P, Bautmans I. The influence of strength training on muscle activation in elderly persons: A systematic review and meta-analysis. Experimental Gerontology [Internet]. Elsevier Inc.; 2014;58:58–68. Available from: http://dx.doi.org/10.1016/j.exger.2014.07.012
26. Pereira A, Izquierdo M, Silva AJ, Costa AM, Bastos E, González-Badillo JJ, et al. Effects of high-speed power training on functional capacity and muscle performance in older women. Experimental Gerontology [Internet]. Elsevier Inc.; 2012;47(3):250–5. Available from: http://dx.doi.org/10.1016/j.exger.2011.12.010
27. Orssatto LB da R, Moura BM De, Sakugawa RL, Radaelli R, Diefenthaeler F. Leg press exercise can reduce functional hamstring: quadriceps ratio in the elderly. Journal of Bodywork and Movement Therapies [Internet]. Elsevier Ltd; 2018;22(3):592–7. Available from: https://doi.org/10.1016/j.jbmt.2017.09.023

The Swedish Journal of Scientific Research

Scientific Article

Positive Affect and Negative Affect Scale PANAS: Tunisian Sport and Exercise Context

Driss Boudhiba[1]*, Noureddine Kridis[2]

[1]Assistant-Professor at Higher Institute of Sport and Physical Education, Ksar-Saïd, Tunisia, University of Manouba (driss.boudhiba@issep.uma.tn/GSM: 00216 25 81 21 44 (member of the Laboratory of Clinical Psychology), [2]Lecturer at Faculty of Humanities and Social Sciences, University of Tunis, Tunisia.

ABSTRACT

Objectives: We aimed to adapt an instrument which is one of the most used in studies of emotions and mental evaluation, therefore we tried to verify if it is still applicable in sport domain and propose a Tunisian version pf the scale. **Method:** An experimental approach was used, plying the scientific research methods such as the linguistic adaptation, the factorial and statistical analysis of our data. **Results:** The varimax rotation with only 15 items alpha Chrombach improves .65 to .72 by removing the items (9, 10, 12, 16 and 17). Hence, the possibility of abbreviated 15 items instead of 20 was one of our goals, namely to create a new sensitive faithful and valid tool adapted to the Tunisian athlete population. **Conclusion:** Psychometric evaluation confirms an inter-sample stability, internal reliability, temporal stability, a transcultural factorial invariance, and the validity of the convergence criteria.

Keywords: Emotions, sports, mental efficiency, scale, scientific research

INTRODUCTION

Competition is the best situation in which emotions are at their peak. Positive Affect and Negative Affect. PANAS; Watson, D., Clark, L. A, and Tellegen, A. (1988)is a tool designed to identify affective and emotional factors and their impact on performance. The list of self-attributed adjectives contains ten series of two items each dimension to measure positive affect (active, alert, attentive, determined, enthusiastic, excited, inspired, interested, proud and strong) and negative affect (fearful, intimidated, distressed, guilty, hostile, angry, funky, nervous, anxious and frustrated). The PANAS is administrated to measure emotional states of mood and the features of them depend on the structure of time due to the instructions (Watson and Clark, 1997).

Access this article online

Website: http://sjsr.se/

ISSN: 2001-9211

Combined with adequate psychometric properties, this scale is used in the social field (Koestner, Lekes, Powers, and Chicoine, 2002), in Health (Roberts, Dimsdale, East, and Friedman, 1998), in Labor (Bowman and Stern, 1995), in Education (Gumora and Arsenio, 2002) and in sport psychology (Crocker and Graham, 1995).

A research carried out by Thompson (2007) subjected the built of PANAS to develop a short version. Results in the release (I-PANAS-SF) to ten items. This validation was performed with (407) subjects, an exploratory quantitative study was applied taking into account the type of cultural background in order to systematically identify what items to remember from the twenty on the version of (Watson et al. 1988).

In another research, Gaudereau, Sanchez, &Blondin (2006)attempted to compare possible factorial structures of the Canadian version of the questionnaire among a sample of athletes from different sport's

Address for correspondence:
Driss Boudhiba, Rue Alahram n°4 Cité Chebbi 1110 Mornaguia Manouba. Tunisia. E-mail: driss.boudhiba@issep.uma.tn

competition levels the first (n = 305) the second is rather with what the authors were intended to (cross/validate) the most suitable model with the sample size. A study conducted by Galinha and Pais-Ribeiro (2005) clarified the concept of affect, based on the review of the literature, that led to the integration of various aspects of the concept, such as; the concept of affect state (emotion), mood (depression and anxiety and affect trait (personality), the various modes, such as, two-dimensionality versus multidimensionality, orthogonality: independence versus bipolarity, inverse correlation between positive affect and negative affect.

However, In tennis, a research led by Kriese (1993) with the assumption that discerning tennis players must remain calm and control their emotions. Starting assumptions of this study showed that the negative affects such as rumination and mood could be negatively correlated to performance scores (1- male athletes and 6 female) that were followed along a sports season and were subjected to a measurement protocol. Kriese shows that rumination is negatively correlated with athletic performance. Except for the mood, it turned out that it tends to produce less effect on the court and the mood is associated with the performance. Finally, as a negative affect, pre-competitive measures (early season) have no correlation with the performance. Athletes who have not played well reflect more of negative effect after the meeting. However, for positive affect, and even the earliest measures in the season will line up with no performance measurement, the results (before/after) will not correlated to any measurement of performance.

METHOD

We choose the PANAS in order to explore emotions in our sample that are belonging to three types of sports, positive and negative effects, their impact on the efficiency and the competitive performance. First, we start with the development of a preliminary version. Subsequently, the evaluation of the reliability and validity of the instrument consists in factor analysis called "exploratory" and a search for internal consistency.

Participants

To carry out this study, we chose athletes from team, individual and combat sport, N 156 (men 109 and 47 women;18.97 ± 2.73 years).All young athletes (pupils and students) with educational average mean level(12.76 ± 2.82 years) (Table 1).

Procedures

We have translated the Arabic simple scale, and back translation (Forward/Backward translation) translation tools are French/Arabic dictionaries. We asked a university professor to translate our own translation Arabic to French. We applied concurrent evaluations and content and analyzed the reliability and validity of research built by the factor structure to assess, the internal consistency.

RESULTS

Main Analysis

The sample consisting of 156 all athletes from different sport specialties. All young, adults men and women that were chosen as volunteers who agreed to take the test half an hour before the competition. Analyses show a normal distribution and the lack of significant difference p> 8.26. Results show for the Positive Affect an average mean of 37.88 ± 5.20. However, in the Negative affect an average mean of 20.51 ± 6.26. For the total score the average mean is 58.40 ± 8.26.The subgroup of109 athletes men on positive affect obtains an average mean of 38.24 ± 5.16. However, for Negative Affect the average mean is 20.15 ± 6.45. The total score of average mean for men is 58.40 ± 8.32 (Table 2).

However in women's subgroup n 47, the average mean of positive affect is 37,04 ± 5.25and for negative affect average mean 21.36 ±5.76 and the total score mean for

Table 1: Descriptive statistics N156

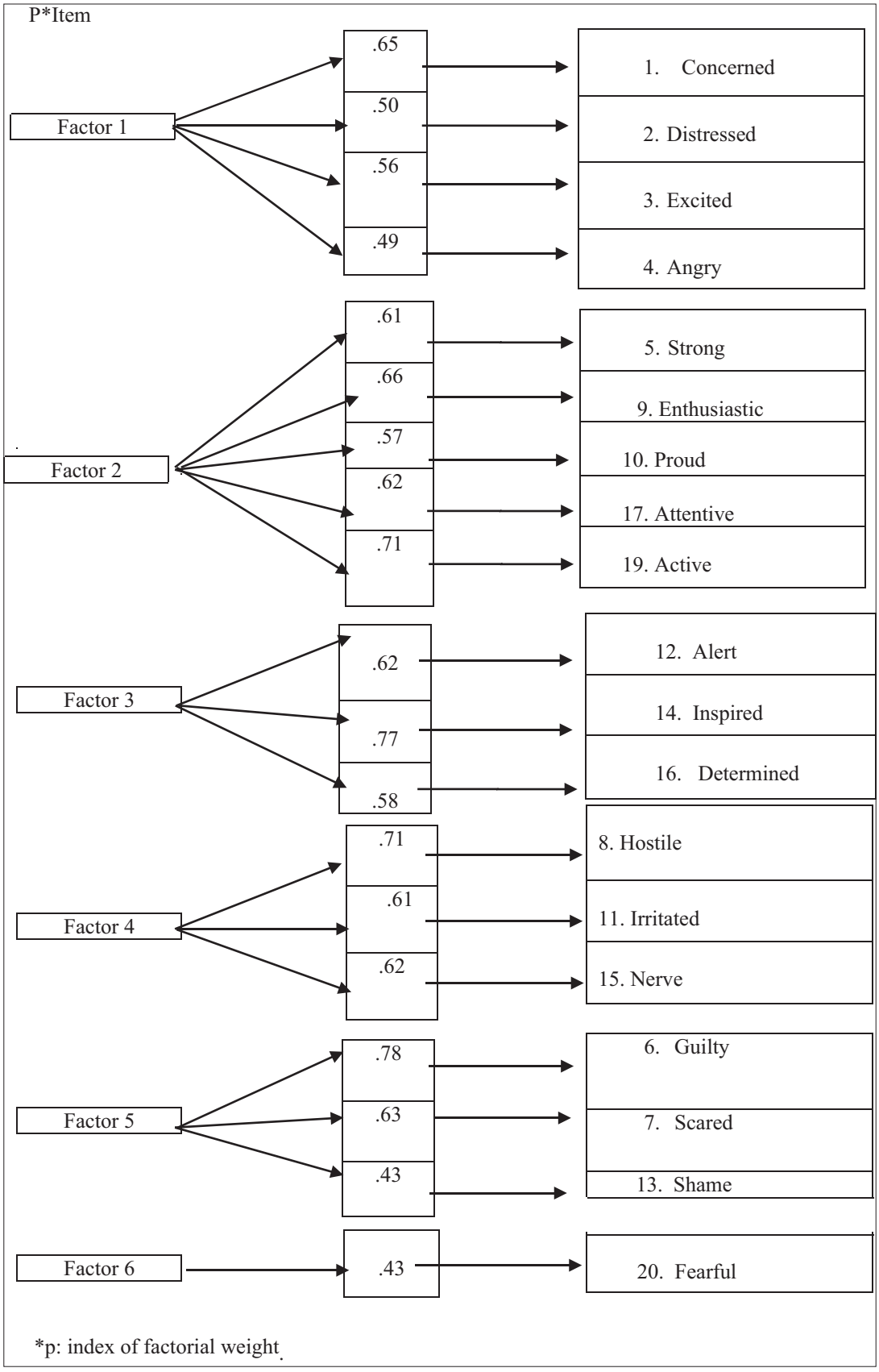
	Men	Women	Total
Sample size	109	47	156
Age	18,81 (2.35)	18,97 (3.47)	18,97 (2.73)
Level of education	12,68 (2.40)	12,76 (3.62)	12,76 (2.82)

Table 2 : Descriptive Statistics PANAS Men n109

	Sample size	Mean	SD
Positive affect	109	38.24	5.16
Negative affect	109	20.15	6.45
Total	109	58.40	8.32

Table 3: Descriptive Statistics PANAS Women n 47

	Sample size	Mean	SD
Positive affect	47	37.04	5.25
Negative affect	47	21.36	5.76
Total	47	58.40	8.21



Phigure 1: Distribution of the different PANAS factorial weight Among the Tunisian sample

women's subscale of positive affect and negative affect is 58,40 ± 8.32 (Table 3).

Factorial Analysis

Factorial analysis performed on data collected after placing 156 athletes from various sport specialties girls and boys practicing team sports, individual and combat in pre-competitive situation, thirty minutes before the competition led to identify six factors, as following:

Factor 1: Item 1 (concerned) to .65, item 2 (distressed) .50, item 3 (excited) to .56, item 4 (angry) at .49. Factor 2: item 5 (strong) to .61, item 9 (excited) to .66, item 10 (proud) to .57, item 17 (attentive) to .62 and item 19 (active) to .71. Factor 3: 12 item (alert) to .62, item 14 (inspired) to .77, and item 16 (determined) to .58. Factor 4: 8 item (hostile) to .71, item 11 (irritated) to .61 and item 15 (nerve) to .62. Factor 5: this factor that consists of three items: 6 (guilty) to .78, item 7 (scared) to .63 and item 13 (shame) to .43. Factor 6: a single item 20 (fearful) to .71.

The analysis of inter-item correlations were subjected to principal components factor analysis followed by varimax orthogonal rotation procedure to isolate the best items saturating the factors studied. A second analysis was performed on selected items. In order to provide the best possible compromise between the extent of the scale and its internal consistency.

The varimax rotation with only 15 items alpha Chrombach improves .65 to .72 by removing the items (9, 10, 12, 16 and 17). Hence, the possibility of abbreviated 15 items instead of 20 was one of our goals, namely to create a new sensitive faithful and valid tool adapted to the Tunisian athlete population.

DISCUSSION

Regarding Gaudreau (2006) attempts' to compare possible factor structures of the Canadian version of the scaleamong 305 athletes, our factorial analysis performed on datas collected among 156 athletes aligns with the assumptions of three factors Gaudreau's construct. Moreover, comparing to those of Galinha et al. (2005). Results of this study are alined with the existence of a construct similar to the original hypothesis and aligns with Watson et al. (1988).

Furthermore, to study the robustness of the positive and negative affect scale, Tuccitto et al. (2008) conducted a search among a sample of 223 athletes, suggesting that the PANAS scores are reliable and explaining the wide proportions of the variance of items. Thus, we supported the veracity of such results as part of our research, which aligns to internal validity of the PANAS.Our study attempted to bring to light to some correlations, just after calculating the normal distribution indices, using descriptive statistics, we submitted these results to an analysis of variance through which we discovered a significant difference in the relationship (performance/total score of PANAS). Based on the results of our study sample subjected to the repeated measures protocol in pre-competitive situation, we support and confirm these results revealed by Kriese (1993) considering emotions the best predictors of performance. The attention cautiously underlined the fact that emotions, particularly positive affect appears three times positively correlated with the performance. Hence, focused on the importance of this condition in achieving good results. This could depend of course on other variables such as; the type of competition, the type of sport and various socio-affective conditions, presence or absence of parents, playing at home or in the opposition and the level of expertise.

Matching results carried out by Thompson et al. (2007) subjected the built of PANAS to develop a short version. Results in the release (I-PANAS-SF) to ten items. The validation was performed with (407) subjects, an exploratory quantitative that study was applied taking into account the type of cultural background in order to systematically identify what items to remember of the twenty on the version of (Watson et al. 1988).

CONCLUSION

Finally, a psychometric evaluation confirms an inter-sample stability, internal reliability, temporal stability, a transcultural factorial invariance, and the validity of the convergence criteria. Indeed, we invite colleagues to use this new shorter version, that would facilitate the exploration of the affective components and the study protocols, especially if the battery is quite long.

REFERENCES

Bowman, G. D., & Stern, M. (1995). Adjustment to occupational stress: The relationship of perceived control to effectiveness of coping

strategies. *Journal of Counseling Psychology, 42*, 294–303.

Crocker, P. R., & Graham, T. R. (1995). Coping by competitive athletes with performance stress: Gender differences and relationships with affect. *The Sport Psychologist, 9*, 325–338.

Galinha, I. C., & Pais-Ribeiro, L. (2005). Contribuição para o estudo da versãoportuguesa da *Positive and Negative Affect Schedule* (PANAS): I – Abordagemteóricaaoconceito de afecto. *AnálisePsicológica, 23,* Tuccitto, D. E., Giacobbi, P. R., & Leite, W. L. (2010). The internal structure of positive and negative affect: A confirmatory factor analysis of the PANAS. *EducPsychol Meas*. 70:125–141.

Galinha, I. C., & Pais-Ribeiro, L. (2005). Contribuição para o estudo da versãoportuguesa da *Positive and Negative Affect Schedule* (PANAS): I – Abordagemteóricaaoconceito de afecto.*AnálisePsicológica, 23, 2*.

Gaudereau, P., Sanchez, X., & Blondin, J-P. (2006). Tester les structure factorielle du PANAS à travers des échantillons franco-canadiens. *European Journal of Psychological Assessment*; Vol. 22(4): (pp.240-249).

Gumora, G., & Arsenio, W. F. (2002). Emotionality, emotion regulation, and school performance in middle school children. *Journal of School Psychology*. 40:395–413.

Koestner, R., Lekes, N., Powers, T. A., & Chicoine, E. (2002). Attaining Personal Goals: Self-Concordance Plus Implementation Intentions Equals Success. *Journal of Personality and Social Psychology,Vol. 83, No. 1, 231–244*. DOI: 10.1037//0022-3514.83.1.231

Roberts, K. R., Dimsdale, J., East, P., & Friedman, L. (1998). Adolescent emotional response to music and its relationship to risk-taking behaviors. *Journal of Adolescent Health, 23*, 49–54.

Thompson, E.R. (2007). Development and Validation of an Internationally Reliable Short-Form of the Positive and Negative Affect Schedule (PANAS). *Journal of Cross-Cultural Psychology*, Vol 38(2), 227-242.

Watson, D., Clark, L. A, & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *AJ PersSoc Psychol. 54(6):1063-70*.

Watson, D., & Clark, L.A. (1997). Measurement and mismeasurement of mood: Recurrent and emergent issues. *Journal of Personality Assessment, 68*, 267–296.

The Swedish Journal of Scientific Research

Original Article

Impact of Adapted Aquatic Physical Activity on Social Understanding of Two Young Autistic People (Case of Swimming)

Rahali Dalel[1], Jelleli Hilmi[1,2]*, Khader Souha[1-3]

[1]High Institute of Sports and Physical Education, Kef, University of Jendouba, Tunisia, [2]Laboratory of Clinical Psychology Intersubjectivity and Culture, (LR16ES01), [3]Research Unit, Sportive Performance and Physical Rehabilitation "S2PR" (UR13JS01)

ABSTRACT

Social understanding in children with autism represents a barrier to the integration of autistic people into Arab societies and specifically Tunisian society. Considered as a handicap, autism remains a real public health problem. If the contact with the water allows a moment of playing and relaxation, the practice of regular aquatic activities can become a real asset in the daily life. The present study aims to prove that regular water activities for children with autism could improve the social understanding of autistic people and thus facilitate their social integration into Tunisian society. To do this, we used two investigative tools, namely semi-directive interviews and direct and non-participatory observation with two young autistic Tunisians, a girl and a boy. The results of the analysis of the data of the different themes (motor stability, imitation, pointing, sharing and eye contact) indicate great improvements in social understanding.

Keywords: Autism, adapted physical activity, social understanding

INTRODUCTION

The quality of social understanding among children with autism is a big problem in society. As a disability, autism represents a real public health problem.

«Autism is particularly characterized by a disturbance of social relations, that is to say that people with autism have difficulty communicating, in a social situation, appropriately» (Jeantin, et al. 2009).

This developmental pathology generates a disorder of several process areas, including social understanding.

Access this article online

Website: http://sjsr.se/

ISSN: 2001-9211

In fact, autistic children have difficulties in developing interpersonal relationships, a lack of reactivity to others, problems of knowledge of social and moral values or of interest to them, whereas it is essential in these situations to anticipate the social environment. We have therefore chosen an integration program that consists in proposing a practice of adapted physical activity (swimming based on aquatic games) since this discipline represents "a privileged way for the child with autism to develop his or her abilities in all the functions that need to be improved, both in the sensorimotor fields, as well as in those of communication and socialization, because it provides a motivating framework, linked to the pleasure of practicing sports and to esteem of self it engenders" (Massion, 2006).

METHODS

We based our research on two investigative tools: (i) semi-directive interview and (ii) direct and

Address for correspondence:
Jelleli Hilmi, Higher Institute of Sport and Physical Education of Kef, Boulifa University Complex, Kef, Tunisia.
Phone.: 00216. 95. 53. 74. 71. E-mail: h.jelleli@gmail.com

non-participatory observation. Interviews and the observation were conducted with two Tunisian young autists, a girl (named MT) and a boy (named RS) (Tables 1 and 2).

Before starting our research, we obtained the agreements of the parents of our two interlocutors in the form of signed consents. The autism of our two interlocutors was certified by experienced psychologists from an early age. The interview was inspired by the differential scale of intellectual efficiency (E.D.E.I) (Ben Rejeb, 2001) and contains the following dimensions:

1- Social references, 2- The rules of social behavior, 3- The code of interpersonal relations, 4- Knowledge of social values and 5- Knowledge of moral values.

The observation grids are made with regard to following different social themes: Motor stability, The sharing, imitation, the score, visual contact. The experiment took place during the May and June 2018 in the swimming pool of the Higher Institute of Sport and Physical Education of Kef, Tunisia. All sessions are held regularly every Monday, Wednesday and Saturday at 14h (Table 3). So, we did a study of the interactive abilities of autistic children based on water games with the use of balls of different sizes and colors, in situations of social interaction with coaches and other children.

RESULTS

Thanks to the synthesis of the data in the observation grids of two autistic children, we notice several evolutions in the different social domains (Tables 4 and 5). At the end of the observation, we identified that these two autistic children were at the extremes of social understanding:

Our study tends to show that aquatic activities can improve problems related to the dysfunction of children with autism. Yilmaz et al., (2004) have shown that swimming allows children with autism to develop a better perception of the body and an improvement in social integration.

The participation of people with autistic disorders in a collective activity could give them a sense of belonging to a group and thereby facilitate their social integration. The purpose of this research was to see if aquatic activities would have a positive influence on the communication and social understanding of young people with autism.

Table 1: Clinical vignette of MT

Date of birth	Number of brothers and their ages	Special interests	Mother's age	Father's age	History of illness
17/08/2009	1 brother (15 years)	Swimming	47	55	-The discovery of the disease: March 20, 2013 - At the age of 1 year and a half "MT" utters a few words as well as all the children of this age: Papa, Mama, ... -MT began to lose language at the age of three. -In 2013 Ms. H began to consult professionals in the field. -First exam: April 06, 2013 with the child psychiatrist. April 08, 2013: with the speech therapist -According to the results of the professional exams "I was shocked". The child psychiatrist informs me that my daughter was autistic. -5 years of therapy from March 2013 until today.

Table 2: Clinical vignette of RS

Date of birth	Number of brothers and their ages	Special interests	Mother's age	Father's age	History of illness
21/10/2001	-	Swimming	42	47	-RS is my first child who is a boy. -At the age of 2 he uttered no words. -Uncarious behaviors "he does not fix the eye and he does not point". - Signs of abnormality in terms of language and gait. -Some turmoil crises. - At the age of 4 years, consult a child psychiatrist. -After the diagnosis I was shocked. -My mother worries too much for the future of her son, that's why she refuses to have another child (carrier of autism). -15 years of therapy until today.

Table 3: Educational intervention project

No. of sessions	Objectives
S1 to S5	Being able to develop motor stability in aquatic activities: the body and the water (throwing, catching, jumping, ...), sensory exploration of objects (shooting, passing, receiving).
S6 to S10	Being able to throw the ball and react following a visual signal.
S11 to S14	-For the subject n ° 1 (MT) : To be able to arouse the desire to accept the collective games. - For subject n° 2 (RS) : Being able to arouse desire and act in the aquatic environment. (RS).
S15 to S18	To be able to improve social imitation (for example, to make an agreement or goodbye of the hand) and to carry out a social exchange (with non-verbal communications).
S19 to S24	Being able to maintain pointing gestures.

DISCUSSION

The results of the interview data analysis and observation grids show a change in motor stability, eye contact, sharing, imitation, and pointing, as "The environment Aquatic offers a space of mediation particular for the autistic persons by its consistency and what it produces in matter of sensoriality " (Le Paven, et al. 2007).

Previous studies, already showed that APA may be beneficial for autistic people. Sport would develop their social understanding, which can make them more empowered in their lives (Brun, 2014; Bonnon et al. 1992; Kwiat et al. 1999; Dugas & Moretton, 2012).

Our results are consistent with those of Dykens & Cohen (1996), Grandisson et al. (2012); Gençöz (1997) and Khosla et al. (1988) who showed that sport was more than beneficial for people with autistic disorders.

According to these studies, adapted physical activities are beneficial for people with different disorders, sports activities are considered as a factor of well-being.

"It must be remembered here that the child with autism is a developing being, who learns as the normal child, but at a slower pace and that the dysfunctions that it presents can be compensated in whole or in part by the exercise". (Massion, 2006).

Aquatic activities are in fact a privileged way for the child with autism to develop his abilities in all the functions that need to be improved, as well in the fields of social comprehension, as in those of communication and socialization, because they provide a motivating framework, linked to the pleasure of sport. Our results indicate major improvements in the social understanding of young autistic people following the practice of aquatic physics activities.

Table 4: Evolutions in the different social domains (MT)

Number of sessions	Motor stability	Visual contact	The sharing	Imitation	The score
S1	-	-	+	-	-
S2	+	-	+	-	-
S3	+	-	+	+	-
S4	+	+	+	+	+
S5	++	+	+	+	+
S6	++	+	+	+	+
S7	++	+	++	+	+
S8	++	+	++	+	+
S9	++	+	++	+	+
S10	++	+	++	+	+
S11	++	+	++	+	+
S12	++	+	++	+	+
S13	++	+	++	+	++
S14	++	+	++	+	++
S15	++	+	++	+	++
S16	++	++	++	+	++
S17	++	++	++	+	++
S18	++	++	++	+	++
S19	++	++	++	+	++
S20	++	++	++	+	++
S21	++	++	++	+	++
S22	++	++	++	+	++
S23	++	++	++	++	++
S24	++	++	++	++	++

(-) (0) = Total absence, (+) (1) = Average progression, (++) (2) = An evolution

If we take each subject apart, we notice that sharing and imitation are two elements of success that have set an evolution from the first sessions. Indeed, Piaget (1948) confirms that "the phenomenon of imitation among young children as a process that participates in the appearance of the "symbolic function" insofar as it ensures the passage between sensory-motor intelligence and pictorial representation. This capacity facilitates, in particular, the acquisition of social language and know-how and consequently "communication and language". (Piaget,1948).

Table 5: Evolutions in the different social domains (RS)

Number of sessions	Motor stability	Visual contact	The sharing	Imitation	The score
S1	-	-	-	+	-
S2	-	-	-	+	-
S3	-	-	+	+	+
S4	-	+	+	+	+
S5	+	+	+	+	+
S6	+	+	+	+	+
S7	+	+	++	+	+
S8	+	+	++	+	+
S9	+	+	++	+	+
S10	+	+	++	+	+
S11	+	+	++	+	++
S12	+	+	++	+	++
S13	+	-	++	+	++
S14	+	-	++	+	++
S15	+	+	++	++	++
S16	+	+	++	-	++
S17	+	+	++	-	++
S18	++	+	++	++	++
S19	++	+	++	++	++
S20	++	+	++	++	++
S21	++	+	++	++	++
S22	++	++	++	++	++
S23	++	++	++	++	++
S24	++	++	++	++	++

Thorndike (1928) was one of the first authors to study the phenomenon of imitation and its role in child development. He defines imitation as "learning to do an act by seeing it do". (Bendiouis, 2015).

When MT, we notice that there is a progression in motor stability after one day. Compared to RS, in the first four sessions motor stability is zero, which requires more time for us to reach a satisfactory level of learning.

Although visual contact in both autistic children remained stagnant in the first three sessions. Since autistic people take time to adapt and integrate into a new environment and especially with new people.

For MT the scoring domain has evolved from the third session, when at RS it is from the second session that we observe a good improvement. Physical activity is essential for the child with autism awareness of his body and its safe environment, knowing that it helps to reduce his frustrations. Through Adapted Physical Activities, children with autism can learn in a social environment and thus develop their social understanding.

CONCLUSION

During this research, we showed the nature of the contribution of a better quality of life (regular playful aquatic practice) for children with autism would be able to be beneficial to the understanding and social adaptation of young people autistic. If contact with water allows a moment of relaxation and play, the practice of regular aquatic activity can become a real asset in the daily life of children with disabilities.

REFERENCES

Bendiouis, S. (2015). Imitation and communication in young children with autism (Doctoral dissertation, University Paul Valery-Montpellier III).

Bonnon, M., Therme, P., & Noël-Jorand, M. C. (1992). Aspects psychologiques de l'adaptation à l'altitude. *Recherches en APS*, *3*, 463-481.

Brun, A., & Roussillon, R. (2014). *Formes primaires de la symbolisation*. Dunod.

Dugas, E., &Moretton, J. P. (2012). Quel choix d'activités physiques et sportives dans une perspective d'apprentissage pour des jeunes ayant des troubles cognitifs ou des troubles psychiques?. *ALTER-European Journal of DisabilityResearch/Revue Européenne de Recherche sur le Handicap*, *6*(1), 39-56.

Gençöz, F. (1997). The effects of basketball training on the mala daptive behaviors of trainable mentall yretarded children. *Research in developmental disabilities*, *18*(1), 1-10.

Grandisson, M., Tétreault, S., & Freeman, A. R. (2010). Le sport: promoteur de la santé et de la participation sociale en Déficience Intellectuelle. *Revue Francophone de la Déficience Intellectuelle*, *21*, 54-65.

Jeantin, A., Blanc, R., Fontaine, R., & Barthelemy, C. (2009). Neuropsychologie des difficultés d'ajustement social de l'enfant avec autisme en situation d'intégration scolaire en milieu ordinaire: revue de questions. *Approche Neuropsychologique des Apprentissages chez l'Enfant (ANAE)*, *101*, 59-68.

Khosla, B., Malhotra, R., & Dutt, V. (1988). Sports as intervention for socialization and integration of the mentally handicapped. *Indian Journal of Disability&Rehabilitation*, *2*(2), 19-23.

Le Paven, M., Roesslé, S., Roncin, E., Loquet, M., &Léziart, Y. (2007). La dévolution dans les activités physiques sportives et artistiques non scolaires. *Education et didactique*, *1*(3), 9-29.

Massion, J. (2006). Sport et autisme. *Science & sports*, *21*(4), 243-248.

Ménesguen, Y., Smirr, J. L., Pillet, G., Alléaume, R., Maruani, A., Zaquine, I., &Jacubowiez, L. (2008). Sources de photons intriqués en polarisation: travaux pratiques de physique quantique. *Bulletin de l'Union des Physiciens*, *102*, 61-80.

Nadel, J. (2011). Imitate to grow, development of the baby and the child with autism. Paris: Dunod.

Piaget, J. (1948). Le langage et la pensée chez l'enfant: Études sur la logique de l'enfant.

Rejeb, R. B. (2001). Intelligence, test and culture: the Tunisian context. Editions L'Harmattan.

The Swedish Journal of Scientific Research

Original Article

The Reciprocal Style In Teaching Tennis For Students Aged 14-15 Years

Kyritsopoulos D[1]*, Athanailidis I[1], Mantis K[1], Digelidis N[2]

[1]Democritus University of Thrace, Komotini, Greece, Department of Physical Education & Sport Science, [2]University of Thessaly, Trikala, Greece, Department of Physical Education & Sport Science

ABSTRACT

The aim of the present study was to evaluate the reciprocal style of teaching, in typical tennis strokes, such as forehand and backhand. A sample of 102 children, aged 14-15, who had no previous experience in tennis participated in this study. Students were engaged in 12 lessons held in their school environment. The experimental group was subjected to experimental intervention for 6 weeks in the independent variable which is the reciprocal teaching method for strokes, while the control group was not subjected to any intervention and was not trained following this teaching style. Data was processed by statistical analysis through t-test for independent samples. The results showed that the reciprocal style of teaching had increased the mean of consecutive strokes regardless of gender, with the experimental group showing a significant improvement in performance in the measured wall test, in comparison to the control group which showed no improvement.

Keywords: Teaching styles, reciprocal teaching style, forehand, backhand, tennis

INTRODUCTION

Tennis is admittedly a difficult but enjoyable sport which, during the last 15-20 years, has undergone a general-progressive development concerning the various methods of teaching its basic strokes (Crespo, 1999). The term teaching method is defined as the set of planned actions and the systematic way of learning which aim at achieving predetermined goals. The objective of teaching is to connect students in consequential goal-orientated activities with the aim of achieving instructional outcomes through lessons (Mosston & Ashworth, 2008; Rink, 2002).

Access this article online

Website: http://sjsr.se/

ISSN: 2001-9211

Concerning the importance of research and considering that one of the primary goals of physical education in secondary education is to have children positive and psychomotor experiences so that by finishing school they continue to work out their whole life, we understand that those teaching methods and styles should be used which, in conjunction with the appropriate content, aim at promoting and developing more positive attitudes to lifelong learning.

Australian tennis coaches believe they use a range of teaching styles during their coaching sessions throughout the year ((Hewitt, Edwards, & Ashworth, 2011)). According to guru of teaching styles Muska Mosston, the anatomy of teaching style is made up of planning, execution and evaluation decisions, and no one teaching style is superlative for every classroom teaching situation (McCullick & Byra, 2002).

In the fields of teaching Physical Education (PE) and sports, teaching methods of learning-practicing skills can be categorized into: the total method during which

Address for correspondence:
Kyritsopoulos D, Democritus University of Thrace, Komotini, Greece, Department of Physical Education & Sport Science.
E-mail: kyritsodimitris@yahoo.gr

skills-strokes are taught as a whole, the part method during which skills are taught and practiced in separate parts which are then combined back into the whole, the part-progressive method (a variation of part method) in which different parts of a skill are taught and learned independently and then combined sequentially, as well as the blended method which is a combination of total and part methods of teaching (Grivas, 2015).

In Inductive or Synthetic method of teaching, skills are presented from part to whole, from specific to general, from experience to theory, from specific to abstract, from processing individual concepts to forming general terms, rules and principles. In total method, motor skills are presented to students as a whole. During the very first moments of practice stage, students have to face difficulties while practicing a movement in its simplest form and the outcome of learning becomes obvious, with motor-intelligent students showing higher performance (Papandreou, 2001).

In Deductive or Productive or Analytical method of teaching, skills are presented from whole to part, from general to specific, from theory to experience, from abstract to specific, from processing general terms, rules, principles to ascertaining their individual applications.

Students experiment, make efforts and, at the same time, are monitored and assessed by the coach developing a controlled initiative, through a teaching method which favors collaborative spirit, but disadvantages more complex forms of movement in which potential risks of miscomprehension are posed (Mavvidis, Teaching and Training in Tennis, 2005).

The need of Mosston and Ashworth (1986) not to impose his views on his students in teaching Physical Education has led to the creation of α set of teaching styles in the field of PE, the so-called "Spectrum of Teaching Styles".

In Physical Education, the methods used in recent decades at the global level are the Spectrum of Teaching Styles introduced by Mosston. It is a way of classifying teaching methods based on the dynamics of teaching, where each method provides a framework within which an educator can teach (Digelidis, Bogiatzi, Chatzigeorgiadis, & Papaioannou, 2006). The majority of decisions are taken by the teacher, student or both in one or all of the three phases of the process teaching (planning – conducting - evaluation). These decisions are the means of achieving the objectives of each course which, in turn, serve the general objectives of the course and, by extension, the aims of physical education (Mosston & Ashworth, 2002).

The primary Principle-Axiom of the Spectrum leads to the conclusion that there is not only one single teaching method but there are numerous and each one is differentiated depending on who the decision-maker is, the teacher or the student, resulting to cultivating and meeting different objectives. Depending on the goals we wish to achieve, this decision-making process should involve two primary mechanisms: a) the mechanism of copying- Reproduction, which involves the potential of the person to reproduce what is already known, and b) the mechanism of creating- Production, that is the mechanism which creates things which have not yet been invented.

Teaching methods are also classified according to two general headings: productive and reproductive. In reproductive or direct teaching methods the teacher is the one who makes most of the decisions. Productive or indirect methods allow the students more decision making. Reproductive styles are direct, teacher-centered and theoretically based on Behaviorism; learning derives from the student and Cognitive learning becomes dominant (McCullick & Byra, 2002).

In other research studies, it was found that the Command Style, the Practice Style and the Reciprocal Style were equally effective in teaching motor skills to young students (Golberger, Gerney, & Chamberlain, The effects of three styles of teaching on the psychomotor performance of fifth grade children, 1982; Golberger, Direct styles of teaching and psychomotor performance, 1983) and university students (Beckett, 1991; Boyce, 1992; Pellet & Harrison, 1995; Ernst & Byra, 1998; Mosston & Ashworth, Teaching physical education, 2002).

In a three-week study conducted by Cai (1997), responses and reports of 121 college students in the United States of America were investigated. Three different teaching styles were applied (Command, Reciprocal and Inclusion) in a random order. The results indicated that the command style was more effective compared to the other two styles in racquetball and karate.

More feedback is provided when the reciprocal style of teaching is used (Cox, 1986; Byra & Marks, The effect of two pairing techniques on specific feedback and comfort levels of learners in the reciprocal style of teaching., 1993; Ernst & Byra, 1998; Byra, Applying a task progression to the reciprocal style of teaching, 2004; Byra, The reciprocal style of teaching: A positive motivational climate, 2006), while less incidents of antisocial and unwanted behaviors are observed compared to the command and practice styles (Fantuzzo, King, & Heller, 1992)

The reciprocal style of teaching belongs to the cluster of reproductive methods, which are not compared or assessed as such in research studies conducted within this cluster of the Spectrum of teaching styles. Researches on the reciprocal style of teaching is lacking within Greek and international literature, without however comparing or assessing it by that method, given Mosston's assumptions about the consequences of its application, while the effectiveness of this method in Tennis, and more specifically in its basic strokes such as forehand and backhand has not been studied. This paper will attempt to explore-evaluate the R.T.S. in learning - developing the forehand & backhand stroke in tennis in a sample of high schools students

In reciprocal methods, a part of the decisions is handed to the students who as assistant-observers give their peers feedback based on the instructions already given by the teacher. Consequently in the applied teaching method, conditions of immediate feedback and social interactions were cultivated and developed within pairs of students. Another prime objective of the applied reciprocal style was teaching the sport and learning, that is the relatively permanent change of students' behavior and skills which is the outcome of receiving and processing information combined with biological processes.

PURPOSE

The aim of this study was to evaluate the effectiveness of the reciprocal style of teaching in learning - developing motor skills in Tennis (ITF Tennis, 2008) and more specifically on the forehand and backhand strokes in a sample of students aged 14-15 years. The effectiveness of reciprocal teaching method in the two basic tennis strokes was examined. The sample consisted of students from the 2nd Junior High School of Chalkida and the High School of Drosia.

METHOD

The key objective of this study (after students had randomly been assigned to experimental group by conducting an initial measurement- same starting point after the implementation of the reciprocal style, as well) was that decisions should be made at the stage of assessment so that an immediate feedback, the most important feature of this method, could be achieved Students were organized in pairs with each one assigned a specific role. One student performed the task (performer) as in Practice style of the Spectrum, with the only difference being that he/she only interacted with the student observing him/her (observer), while the observer provided individual feedback to the doer and only interacted with the teacher. The teacher observed both students and only interacted with the observer.

The term forehand is used as a base for every tennis stroke made from the right side of the body for a right-handed person, and from the left side for a left-handed person. Forehand is referred to as the most prevalent and important groundstroke covering 70% of groundstrokes in a tennis match (Mantis, Grivas, Kambas, & Zachopoulou, 1998). The term backhand, for a right-handed player, is the shot which is struck from the left side by bringing the racket across the body, at which point the ball is hit, and ends with the hand on the right side of the body. Backhands are mostly used for shots hit while playing in the baseline.

The control group consisted of 34 students (Table 1), while the experimental group consisted of 68 students with age ranging from 14 ± 0,4.

An important aspect of the applied reciprocal style in the experimental group was the task and criteria sheet. Directions to the doer and the observer, performing tasks criteria, examples of comments for feedback and assessment, as well as the duration of exercises or the number of attempts to be made for completion of each exercise were included in this task sheet. Moreover, there was a specific description of the exercise along with samples of verbal behavior to be used as feedback. The task and criteria sheet included pictures and sketches enabling the student-observer to determine when the doer executed each part of the exercise properly (Melograno, 1997; Ennis, Solmon, Satina, Loftus, Mensch, & McCauley, 1999).

Performance of students was measured in the Game against the wall during the first interventional lesson (before) and during the last 12th interventional lesson (after) and specifically in "Wandtest" of Majer P. (1987). In the bibliography, tennis test diagnosis tests mainly refer to "special skill" tests, "wall tests", and tests to the "tennis racket", usually aiming at the success of a target. In "Wall" Testing, the tried-and-tested attempts to achieve, with kicks of the tennis racket ball, a specific target on the wall from a different distance with a particular or non-execution mode. The "Wandtest" of Majer P. (1987) as a "wall test" is a variant of the Dyer tennis-test that has been applied since 1935 to women, beginners and teenagers, and Ronnings Revision of Dyer-Test (Ronning, 1959).

In Wandtest, Forehand and Backhand are initially considered separately, for Weber& Hollmann (1984) require different techniques and tactics. Even the distances selected are 4, 8, and 12 meters. Another difference is the duration of the test. Each of the 3 Forehands in total and 3 in the Backhand tests lasts 30 instead of 60 seconds.

The students who participated in the test had to hit the ball from behind a line within an 8-meter distance from the wall on which there was another line (7 cm) drawn 91 cm from the ground. Each student was provided with a racket and two balls, and when the teacher blew the whistle they dropped the ball on the ground and hit it against the wall aiming above the line, using forehand and backhand technique. Three attempts of 30 seconds each were given, volley stoke was also allowed and the observer assisted verbally and motivated the doer counting only the consecutive attempts during which the doer hit the ball above the line and remained, of course, behind the 8-meter line (there was a basket containing extra balls, as well).

The best performance (more consecutive forehand and backhand strokes) achieved in the three attempts was taken into account and registered, both before and after the interventional research program. The reliability of the test was r=0.90 and its validity between r=0.85-0.90 (Majer, 1987).

After the end of the six-week period, a measurement of successful strokes was conducted for both teams. Mean scores of both teams were compared in order to find statistically important differences. According to the null hypothesis (Ho), there would not be statistically significant differences between the scores of the two teams, while according to the alternative hypothesis (H_1) (one-sided), the experimental group (subjected to intervention) would show higher levels of successful shots compared to the control group (not subjected to intervention). If the null hypothesis was rejected and the alternative was accepted in its place, it could be inferred that the implementation of the new method is effective in the improvement of successful strokes (compared to no implementation at all).

The SPSS 20.00 statistic was used. There were 2 experimental groups: the reciprocal method group and the control group, 2 measurements: initial and final measurement, and gender: boys-girls with measurements in the measurement factor. Afterward, the independent samples t-test was used for the statistic analysis while for the reliability of the scales the Cronbach alpha factor was calculated. Statistically significant differences were observed in the values of the dependent variable between the two teams of students, and therefore, the conclusion that these differences were the outcome of the new teaching method was drawn.

According to the initial plan of the methodology, a premeasurement M1 was to be conducted in the experimental group through random sampling, and at the same time a premeasurement M3 in the control group.

However, based on this type of experimental planning, it was not certain that the second condition of within the teams experimental intervention would be met; that is, both teams would be equal to the values of the dependent variable from the beginning.

For that reason, a premeasurement was carried out at the beginning of the program. Students' scores in performing forehand & backhand skill trials were measured in terms of the number of successful strokes for both teams (experimental and control) before the implementation of the new method, as well as a repeated measurement after the implementation of the new method.

According to the final plan of the method, two measurements M1 & M2 would take place in the experimental group (subjected to intervention) through random sampling. At the same time, during the same time periods, two measurements M3 & M4 would be carried out in the control group (not subjected to any

intervention whatsoever). Measurements M2 & M4 took place after the end of the twelve lessons.

It would be preferred that the premeasurement showed that there are no significant differences in the values of the independent variable for the experimental and control group (M1=M3).

If the new method of teaching these specific strokes were effective, it would be expected that students' scores of successful shots in the experimental group would be significantly higher than the ones of their counterparts in the control group (M2 > M4).

RESULTS

Data processing by applying the independent samples t-test in forehand & backhand stroke (before the implementation of the Reciprocal style of teaching) revealed that the power of the null hypothesis Ho was higher than the value 0.05 (p=0.498), and therefore, the alternative hypothesis H_1, i.e. the means of consecutive strokes were different between the two teams (Table 2 & Figure 1), was not accepted. Therefore, the two groups were considered equal before the implementation of the new teaching style.

The independent samples t-test in forehand stroke (after the implementation of the Reciprocal style of teaching) showed a great significant difference between the two means: 11.63 for the experimental group compared to 6.62 for the control group (Table 3). The power of the null hypothesis was smaller than 0.05 (p=0.000). Therefore, the alternative hypothesis H_1 was accepted; that is, there is a statistically important difference between the means of consecutive strokes of the two teams. It is obvious that the experimental group showed a significant increase in the mean of consecutive scores over the control group which showed no improvement, since it lacked intervention.

Similarly the independent samples t-test in backhand stroke (after the implementation of the Reciprocal style of teaching) showed a great significant difference between the two means: 10.88 for the experimental group compared to 6.61 for the control group (Table 4). Finally it was found that the E.G. improved significantly the average consecutive strokes versus the C.G.

The above tables and graphs show the performances in forehand & backhand in the tennis before the R.T.S. and then. The present research has been found that performances constantly improved in both strokes.

Table 1: Sample by sex and group

Control group (n=34)	Experimental group (n=68)
Males: 22	Males: 33
Females: 12	Females: 35

Table 2: Descriptive Statistical Indicators before R.S.T

Performance	Group	Number of students (N)	MEAN (M)	Standard deviation (SD)
Performance (number of stokes)	1*	68	6.25	3.45
	2*	34	5.72	1.97

*1=experimental group, *2=control group - The criterion value t: t (49,642)=0.683, *P*=0.498
5% was chosen as significance threshold

DISCUSSION

The Reciprocal style of teaching was also studied by Goldberger, Gerney and Chamberlain (Goldberger & Gerney, The effects of direct teaching styles on motor skill acquisition of fifth grade children, 1986; Golberger, Gerney, & Chamberlain, The effects of three styles of teaching on the psychomotor performance of fifth grade children, 1982). In that study, learners formed pairs, and as one learner (doer) performed the task, the other (observer) gave specific feedback to the doer based on information provided by the teacher, in the form of a criteria sheet. When the doer completed the tasks, the doer and the observer switched roles and feedback was given from one learner to another.

According to Goldberger, Gerney and Chamberlain (1982), learners taught in the Reciprocal style of

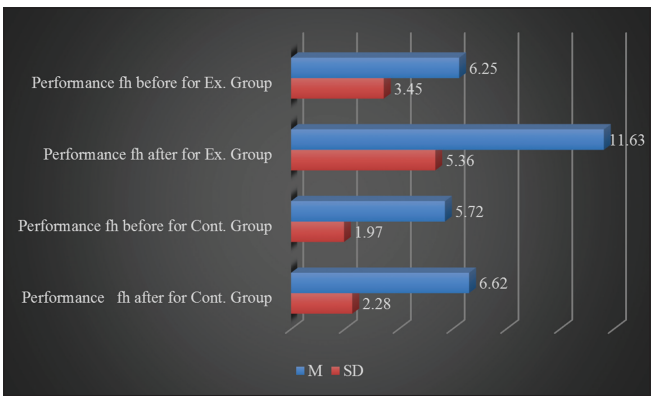


Figure 1: Performance Forehand before & after R.S.T for experimental and control group

teaching not only improved their skills performance but they experienced more interaction, empathy and encouragement from one another, as well.

The results of pairing students using different combinations and applying the reciprocal style were examined by Byra & Marks (1993). The results showed that the students gave more corrective and accurate feedback to the peer - students they were friends with, and respectively student-learners felt more comfortable receiving corrective feedback and guidance from friends than non-acquaintances.

In an attempt to examine how physical, cognitive and social learning could be facilitated in juggling, a study by Ernst and Byra (1998) was conducted. Sixty high school students participated in the study and 8 lessons took place in which the reciprocal style was used. Results indicated that all students in the experimental group improved their scores in skill performance from initial to final test. This was not the case for students in the control group. In the current study, the reciprocal style of teaching, a new teaching style with innovative strategies was implemented during tennis lessons in two different junior high schools of the City of Chalkida.

This research is placing emphasis on the correct implementation of a particular teaching method which falls within the scope of the Mosston's spectrum of teaching styles. The sample consisted of Junior High School Students of the city of Chalkida, the intervention was carried out by experienced PE teachers and it lasted relatively longer that the past ones.

An attempt was made to create the necessary conditions in order to carry out the activity in a spirit of cooperation and creativity and make it virtually more pleasant and joyful; as a positive side effect, more teaching time was saved for the optimum comprehension and acquisition of the desired skills. The goal of this research was to study the effect of an interventional program in teaching tennis as well as the implementation of the reciprocal style of teaching (RST) in students performing the forehand and backhand tasks.

For the first time, students came into contact with the reciprocal style, a completely new teaching strategy and consequently they needed more time to understand and perform the tasks; the new style is very distinct as compared to the older one, which has been used for decades and is rather teacher-centered by asking the students to watch the teacher and perform the activities mechanistically. Undoubtedly, the international bibliography does not include any reference to the use of the reciprocal strategy in teaching tennis.

Analyses of our most important results have shown that the implementation of the new teaching method used in the intervention had very positive effects on the involved students. The RST contributed significantly to the improved performance of the students who belonged to the corresponding test groups. To be more specific, during the first phase, the students of the initial experimental RST groups exercised the forehand and backhand tasks by using the RST and the individual program; these students' performance improved more than the ones' who followed the typical command style.

The predominance of the RST in the results of both kinetic tasks denotes the efficiency of the "participatory observation" in the improvement and maintenance of kinetic tasks. The close relation between "performer" and "observer" possibly encouraged the students for more intensive efforts and better feedback and performance.

The findings of this research confirm the conclusion drawn by previous researches on the efficiency of the RST in learning kinetic skills to students (Goldberger, Gerney, & Chamberlain, 1982; Goldberger, 1983) and young adults (Beckett, 1991; Boyce, 1992). The present analysis' findings have shown that the RST can assist students to acquire kinetic skills in tennis. Also, the statistic figures present an impressive difference between the scores made by the RST style students and the ones following the mainstream school program.

In general, this research has proved the initial hypothesis stating that the scores and the final performance of the students participating in the group following the RST would be obviously higher than the ones of the students following the typical command style process.

Through the 8-meter wall toss test scores, we interpreted the real dimension of the intervention by pointing out the big difference between the initial and final scores gained by the RST group; in addition, the significant role of the program was confirmed by the comparison of the total scores marked down by each test group and the resulting remarkable differences.

The primary aim of this research study was to evaluate the reciprocal style in teaching the basic and typical tennis strokes to students aged 14-15 years, who had no previous experience in tennis. Students were organized in pairs with each one performing the task as in the Practice style, with the only difference being that he only interacted with the student observing him/her, while the observer provided individual feedback and only interacted with the teacher. The observer took on the role of the teacher and the doer the role of the student. Using a criteria sheet which described the exercise and highlighted the skill performance points, the student-teacher (observer) gave feedback to the student-performer (doer).

In order to be able to cope with the requirements of the role, the student-teacher had to observe the student who was performing the exercise, comparing the performance with the information in the criteria sheet, i.e. if the exercise was performed properly and when a problem arose, he/she had to interact with the teacher. During the intervention program backhand was taught in two ways, both with one hand and with two hands. The second way showed that backhand with two hands is clearly more effective in the initial learning phase as shown by the research of Mavvidis A, Konstantinou Ch., Grivas N. & Mantis K., (2013) in adult beginners.

Exercises were performed using criteria sheets designed by the teacher-researcher. On completion of the exercise, the doer and the observer switched roles. The research study was applied for 6 weeks (12 lessons) to students in the third year of High School, aged 14-15, in their school environment. Their performance in the Game against the wall was measured during the first and the last lessons of intervention, and more specifically in "Wandtest" of Majer P. (1987). Student subjects were randomly assigned to two groups (experimental group and control group). The experimental group was subjected to an interventional program in the independent variable which is the new method for strokes for six weeks, while the control group was not subjected to any intervention (not trained following the new teaching style).

The best performance (more consecutive forehand and backhand strokes) achieved in the three attempts was taken into account and registered, both before and after the interventional research program, in which the reciprocal style was evaluated in terms of how much it contributed to learning and developing motor skills in tennis (Crespo,1999; ITF, 2008) and specifically the two basic forehand & backhand strokes. The present study indicated that the new reciprocal style of teaching has a positive effect (an increase in the mean of consecutive strokes) regardless of gender. Moreover, a significant improvement in performance - score in the measured wall test ("Wandtest" of Majer P) was revealed, compared to the control group.

More precisely, the independent samples t-test through SPSS (after the implementation of the Reciprocal style of teaching) showed that, in terms of the two means, a very big significant difference between the two means (from 6.24 before the implementation of the reciprocal style to 11.62 for the experimental group compared with from 5.72 before the implementation of the reciprocal style to 6.61 for the control group).

The power of the null hypothesis was smaller than 0.05 ($p=0.000$). Hence, the alternative hypothesis H_1 was accepted, i.e. there is a statistically significant difference between the means of consecutive strokes of both teams (Table 2 & Figure 2). It is obvious that the experimental group showed a significant increase in the mean of consecutive scores over the control group, which showed no improvement without intervention. This study reinforces the opinion that the reciprocal teaching style is effective and its implementation can

Table 3: Descriptive Statistical Indicators after R.S.T

Performance	Group	Number of students (N)	Mean (M)	Standard deviation (SD)	Std. Error (SE)
Performance (number of stokes)	1*	68	11.63	5.36	0.920
	2*	34	6.62	2.28	0.537

*1=experimental group, *2=control group- The criterion value t:
t (48,409)= 4.699, *P*<0.001
5% was chosen as significance threshold

Table 4: Performance backhand before & after R.S.T. for both groups

Performances	M	SD
Performance Backhand Before R.S.T. for Exper. group*1	6.06	3.01
Performance Backhand After R.S.T. for Exper. group*1	10.88	5.91
Performance Backhand Before R.S.T. for Contr. group*2	5.48	2.75
Performance Backhand After R.S.T. for Contr. group*2	6.61	3.16

*1=experimental group, *2=control group

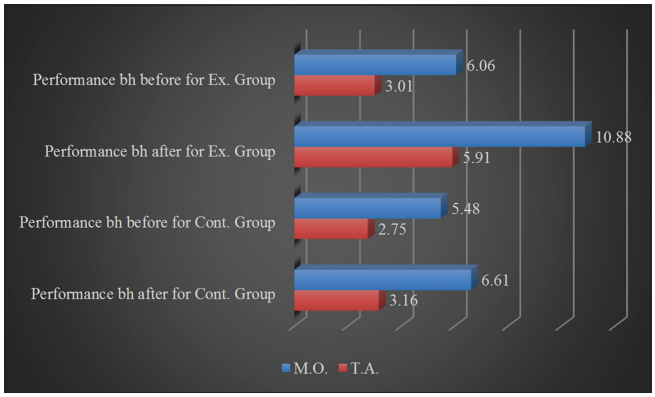


Figure 2: Performance Backhand before & after R.S.T for experimental and control group

contribute positively to the upgrading of Physical Education at Secondary schools in Greece.

CONCLUSIONS

The geographical and age (14-15 years old) restrictions of the selected sample do not enable us to draw general conclusions for the whole of the students' population.

This research was carried out in only two school units. In the future, it will be challenging to repeat it in a larger number of school units which would constitute a higher percentage of the total number of Junior High Schools nationwide. The extended comparison between the RST and the mainstream command style would give us more trustworthy results about the efficiency of RST in teaching tennis to the Junior High School students.

The present study indicated that the reciprocal style of teaching has a positive effect (an increase in the mean of consecutive strokes) regardless of gender. Moreover, a significant improvement in performance - score in the measured wall test ("Wandtest" of Majer P) was revealed, in relation to the control group.

Both students who provided and students who received feedback had much to gain, confirming results of other studies. The potential of students providing other students with feedback led to a greater number of proper task performance, more praise, resulting in greater emotional engagement of students.

Students, by learning to receive and give feedback, broadened their relationships, thus felt comfortable with each other and enriched their personal image since most decisions (compared to other methods) were transferred from the teacher-researcher to the student. Finally, the reciprocal style seemed to be more effective in promoting students' cognitive and social learning than conventional methods of instruction. In the reciprocal style of teaching, a considerable power is granted to the student by the teacher, feedback. The reciprocal style is suitable for improving students' social behavior, since it is obvious that in order to give and receive feedback from a classmate, a student should be interested in his/her classmate and have all the qualities needed for proper communication.

To recapitulate, the reciprocal style of teaching is more effective in the first stage of acquiring motor skills or "cognitive stage" where direct feedback is crucial, especially in teaching a motor skill requiring high "organizational complexity" such as forehand or backhand in tennis. As a teaching style, the reciprocal style can offer variety and make the lesson interesting, shapes the socio-emotional world of students, and offers Physical Education teachers alternative - effective ways of teaching complex skills.

The duration of the intervention and its implementation to all test groups by the same researcher have had possibly negative effects on drawing clear conclusions. In general, intervention projects should last longer and give time to shaping complete and clear perceptions which would lead to safer conclusions. It is proposed to increase the time of experimental implementation so as to be able to make a better assessment of the positive effects of the RST according to the examined variables. However and in the frame of a stricter methodological approach, it is rather impossible for any researcher to control all the potential threats to a research which is carried out in real life conditions and not in the "technically" controlled laboratory conditions.

The field research was selected as our tool of research because it consists a really significant opportunity to verify the validity and efficiency of a theory or hypothesis. In a future attempt, it is advisable to select a larger size of sample, with different qualitative characteristics like sport experience, nationality, social and economic status etc. Also, there should be tested the link and the contribution of the RST to out of school or high performance sports, to sports of different skills and to other school subjects as well.

Finally, the statistical results and the appeal of the program to the students indicate that there should be

a complete four-month tennis course adjusted to the facilities offered by each school unit and incorporated in the school curriculum and supported by training material accessible to any PE teacher.

REFERENCES

Ronning, H. (1959). *Wall Tests for Evaluating Tennis Ability. Master's thesis.* Washington: Department of Physical Education, State College of Washington.

Golberger, M., Gerney, P., & Chamberlain, J. (1982). The effects of three styles of teaching on the psychomotor performance of fifth grade children. *Research Quarterly for Exercise and Sport. 53 (2)*, 116-124. (United States).

Goldberger, M., Gerney, P., & Chamberlain, J. (1982). The effects of three styles of teaching on the psychomotor performance of fifth grade children. *Research Quarterly for Exercise and Sport, 53 (2)*, 116-124.

Golberger, M. (1983). Direct styles of teaching and psychomotor performance. In J. Templin, & J. Olson, *Teaching in Physical Education* (pp. 211-223).

Weber, K., & Hollmann, W. (1984). Neue Methoden zur Diagnostik und Trainingssteuerung der tennisspezifischen Ausdauerleistungs- fähigkeit. [New methods on diagnostic and workout plan of tennis specific endurance abilities]. In H. Gabler, & B. Zein, *Talentsuche und Talentförderung im Tennis* (pp. 186-209). Ahrensberg: Czwalina

Cox, R. (1986). A systematic approach to teaching sport. In M. Pieron, & G. Graham, *Sport pedagogy* (pp. 109-116). Champaign, IL: Human Kinetics, Champaign, Illinois.

Goldberger, M., & Gerney, P. (1986). The effects of direct teaching styles on motor skill acquisition of fifth grade children. *Research Quarterly for Exercise and Sport, 57 (3)*, 215-219.

Mosston,M., & Ashworth,S.(1986).*Teaching Physical Education (31d ed).* Columbus:OH: Merrill.

Majer, P. (1987). *Leistungfahigkeit ung Leistungsstabilitat im Tennis.* Koln: DSHS (Diss).

Beckett, K. (1991). The effects of two teaching styles on college students' achievement of selected physical education outcomes. *Journal of Teaching in Physical Education. 10 (2)*, 153-169.

Boyce, B. (1992). The effects of three styles of teaching on university student's motor performance. *Journal of Teaching in Physical Education. 11 (4)*, 389-401 (United States).

Fantuzzo, J., King, J., & Heller, L. (1992). Effects of reciprocal peer tutoring on mathematics and school adjustment: A component analysis. *Journal of Educational Psychology. 84*, 331-339.

Byra, M., & Marks, M. (1993). The effect of two pairing techniques on specific feedback and comfort levels of learners in the reciprocal style of teaching. *Journal of Teaching in Physical Education. 12*, 286-300.

Pellet, T., & Harrison, J. (1995). The influence of a Teacher's Specific, Cogruen, and Corrective Feedback on Female Junior High School Students' Immediate Volleyball Practice Success. *Journal of Teaching in Physical Education 15*, 53-63.

Cai, S. (1997). College student attitude toward three teaching styles in physiacal education classes. *College Student Journal*, 31.251-260.

Melograno, V. (1997). Integrating assessment into physical education teaching. *Journal of Physical Education, Recreation and Dance, 68*, 34-37.

Ernst, M., & Byra, M. (1998). Pairing learners in the reciprocal style of teaching: Influence on student skill, knowledge, and socialization. *The Physical Educator. 55(1)*, 24-37 (United states).

Mantis, K., Grivas, N., Kambas, A., & Zachopoulou, E. (1998). *Tennis Notes 1.* Komotini: Department of Physical Education and Sports Sciences- Democritus University of Thrace.

Crespo, M. (1999). Teaching methodology for tennis. *ITF coaching and sport science review,19*, 3-4.

Ennis, C., Solmon, M., Satina, B., Loftus, S., Mensch, J., & McCauley, M. (1999). Creating a sense of family in urban schools using the "sport for peace" curriculum. *Research Quarterly for Exercise and Sport, 70*, 273-285.

Papandreou, A. (2001). *Methodology of Teaching.* Athens: Grigori Publications.

McCullick, B., & Byra, M. (2002). Spectrum teaching styles and the national standards for physical education: Introduction. *Teaching Elementary Physical Education. 13(2)*, 6-7. (United States).

Mosston, M., & Ashworth, S. (2002). *Teaching physical education* (5th ed.). Boston: Benjamin Cummings (United States).

Rink, J. (2002). *Teaching physical education for learning* (4th ed.). Boston: McGraw Hill.

Byra, M. (2004). Applying a task progression to the reciprocal style of teaching. *Journal of Physical Education, Recreation, and Dance. 75(2)*, 42-46 (United States).

Mavvidis, A. (2005). *Teaching and Training in Tennis.* Athens: Telethrion.

Byra, M. (2006). The reciprocal style of teaching: A positive motivational climate. *Paper presented at the AIESEP World Congress, The Role of Physical Education and Sport in Promoting Physical Activity and Health.* Jyväskylä, Finland.

Digelidis, N., Bogiatzi, A., Chatzigeorgiadis, A., & Papaioannou, A. (2006). Aggression, personal orientations and internal - external motivation of students in the course of physical education. *Inquiries in Sport & Physical Education, 4*, pp. 57-67.

ITF Tennis. (2008). *Play tennis course manual. 2007.* (N. Γρίβα, Trans.) Αθήνα: Ε.Φ.Ο.Α.

Mosston, M., & Ashworth, S. (2008). *Teaching Physical Education (First Online Edition).* Retrieved 9 2018, from Spectrum of Teaching Styles: www.spectrumofteachingstyles.org

Hewitt, M., Edwards, K., & Ashworth, S. (2011). *Instrument for collecting coaches' self-identified beliefs in relation to the teaching styles they use during coaching sessions throughout the year.* Retrieved 9 2018, from Spectrum of Teaching Styles: https://www.spectrumofteachingstyles.org/literature

Mavvidis, A., Konstantinou, C., Grivas, N., & Mantis, K. (2013). Effectiveness of backhand with one and two hands in teaching adult men beginners in tennis. *Journal of Physical Education and Sport, 3*, 415-418.

Grivas, N. (2015). *Notes for tennis training courses.* Athens: Department of Physical Education and Sports Sciences- National and Kapodistrian University of Athens.