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Test de Step y capacidad de trabajo en jugadoras de voleibol: la paradoja de un mejor rendimiento en las jugadoras mayores

Step test and physical working capacity in female volleyball players: the paradox of better performance in the older athletes

Teste do degrau e capacidade de trabalho em jogadores de voleibol: o paradoxo de um desempenho melhor em jogadores mais velhos

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Resumen: El objetivo del presente estudio fue comparar dos pruebas submáximas de capacidad aeróbica, el YMCA step test y la prueba de capacidad de trabajo físico a 170 ppm (P_{170}) de frecuencia cardíaca (FC), en jugadoras de voleibol femenino. Se analizaron en 152 participantes variables antropométricas, el rendimiento, la frecuencia cardiaca final ($Step_{end}$) y la frecuencia cardiaca en el primer minuto de recuperación ($Step_{rec}$) en la prueba YMCA step test, la P_{170} fue analizada expresando los resultados en valores absolutos ($P_{170,abs}$, W) y relativos ($P_{170,rel}$, W.kg^{-1}). Además, un subgrupo (n=14) fue analizado otra vez después de un año. Los resultados mostraron como el YMCA step test correlacionó altamente ($Step_{rec}$) y muy altamente ($Step_{end}$) con la $P_{170\ rel}$ ($r = -0.58$ and $r = -0.76$, $p < 0.001$, respectively), y con la $P_{170,abs}$ ($r = -0.54$ and $r = -0.68$, $p < 0.001$, respectively). No se encontraron correlaciones entre los porcentajes de cambio en los test de capacidad aeróbica después de un año (p>0.05). La edad presentó una correlación baja a moderada con todos los índices de capacidad aeróbica ($0.23 \leq |r| \leq 0.45$, p<0.05), viendo como las mayores edades tenían una mejor capacidad aeróbica. Basándonos en estos resultados podemos concluir que la prueba YMCA step test (especialmente el parámetro $Step_{end}$) y la P_{170} podrian ser utilizadas indistintamente por entrenadores y preparadores físicos para monitorizar la capacidad aeróbica de jugadoras de voleibol. El paradójico incremento de la capacidad aeróbica con la edad puede ser atribuido a los métodos de evaluación utilizados que están basados en la FC y al descenso de la FC máxima con la edad. Por lo tanto, estos test deberían ser utilizados solo con edades inferiores.
Palabras clave: capacidad aeróbica, grupos de edad, cicloergómetro, tipología de ejercicio, deporte de equipo.
Abstract: The aim of the present study was to compare two popular submaximal tests of aerobic capacity, the YMCA step test and the physical working capacity at heart rate (HR) 170 bpm test (P_{170}), in competitive female volleyball players. The participants (n = 152, age 12.78-41.67 yrs) were examined for anthropometric characteristics and performed the YMCA step test. Heart rate (HR) was recorded at the end of the test ($Step_{end}$) and at the end of the first minute of recovery ($Step_{rec}$). P_{170} test was expressed in both absolute ($P_{170,abs}$, W) and relative values ($P_{170,rel}$, W.kg^{-1}). In addition, a sub-group (n = 14) was tested again one year later. The YMCA step test correlated largely ($Step_{rec}$) and very largely ($Step_{end}$) with $P_{170,rel}$ ($r = -0.58$ and $r = -0.76$, $p < 0.001$, respectively), and $P_{170,abs}$ ($r = -0.54$ and $r = -0.68$, $p < 0.001$, respectively). No correlation was observed among percentage changes in the tests of aerobic capacity over a year (p>0.05). Age correlated low-to-moderately with all indices of aerobic capacity ($0.23 \leq |r| \leq 0.45$, p<0.05), i.e. the older the age, the better the aerobic capacity. Based on the findings of the present study, it was concluded that the YMCA step test (especially the $Step_{end}$ index) and P_{170} might be used interchangeably by coaches and trainers to monitor aerobic capacity of female volleyball players. The paradoxically increase of aerobic capacity with age should be attributed to the assessment methods which were based on HR and to the decrease of maximal HR with age. Thus, these tests should be used only within a short range of age.
Keywords: aerobic capacity, age groups, cycle ergometer, exercise mode, team sport.
Resumo: O objetivo deste estudo foi comparar dois testes de capacidade aeróbia submáximas, o teste do degrau YMCA ea capacidade de trabalho físico a 170 ppm (P170) da frequência cardíaca (FC) em jogadores de voleibol das mulheres. Foram analisados 152 variáveis antropométricas envolvidos, o desempenho, a freqüência cardíaca final (Stepend) e freqüência cardíaca no primeiro minuto da recuperação (Steprec) no teste de etapa de teste YMCA, o P170 foi analisado expressando os resultados em valores absolutos (P170 , ABS, W) e relativo (P170, rel, W.kg-1). Além disso, um subgrupo (n = 14) foi analisada outra vez depois de um ano. Os resultados mostraram que o passo de ensaio ACM altamente correlacionados (Steprec) e muito alta (Stepend) com P170 rel (r = -0,58 e r = -0,76, p <0,001, respectivamente), e o P170, ABS (R = -0,54 e r = -0,68, p <0,001, respectivamente). Não há correlação entre a variação percentual no teste de capacidade aeróbica após um ano (p> 0,05). Idade apresentou uma baixa a moderada correlação com todos os índices de capacidade aeróbica ($|r| \leq 0{,}23 \leq 0{,}45$, p <0,05), observando as idades mais velhas tinham melhor capacidade aeróbica. Com base nestes resultados, podemos concluir que o teste de teste YMCA etapa (especialmente parâmetro Stepend) e P170 pode ser usado indiscriminadamente pelos treinadores e preparadores físicos para monitorar a capacidade aeróbia de atletas de voleibol. O aumento paradoxal na capacidade aeróbica com a idade pode ser atribuído aos métodos de avaliação utilizados, que são baseados no FC eo declínio da frequência cardíaca máxima com a idade. Portanto, estes testes devem ser usados apenas com idades mais jovens.
Palavras-chave: capacidade aeróbia, idade, cicloergômetro, tipo de exercício, esporte de equipe.

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Introduction

Volleyball is a team sport of intermittent high intensity nature, where a combination of physical characteristics, aerobic and anaerobic capacity is necessary in order to perform a sequence of well-coordinated high demanding activities. Although short-term muscle power output, expressed in actions of very short duration and maximal (e.g. jumping, hitting the ball), determines performance, a minimal level of aerobic capacity is necessary to cope with the demands of training and game-play (Sheppard, Gabbett, & Stanganelli, 2009). For instance, during game-play long rallies can last many seconds and fatigue accumulates especially in longer and/or more balanced matches, which emphasize the need of high aerobic capacity (Dávila-Romero, Hernández-Mocholí, & García-Hermoso, 2015; Laporta, Nikolaidis, Thomas, & Afonso, 2015). Therefore, assessing the aerobic capacity in this sport is an important task of coaches and fitness trainers. The aerobic capacity can be measured either by direct (e.g. a graded exercise test that elicits maximal oxygen uptake) or indirect methods (e.g. submaximal test on cycling ergometer) (Ekblom, 2014; Mahar, Guerieri, Hanna, & Kemble, 2011; Saint-Maurice, Welk, Laurson, & Brown, 2014). Compared to the former method that offers accuracy (which is necessary for sports that rely deeply on aerobic capacity such as the marathon) but demands very expensive equipment and specialized personnel, the latter can be used in larger numbers of athletes with only minimal requirements in equipment and expertise (especially in sports, where aerobic capacity is not the main factor of performance, e.g. volleyball).

One of the most widely used indirect tests of aerobic capacity is the Physical Working Capacity at heart rate 170 bpm (P_{170}), an official test of the Eurofit fitness battery, in which participants exercise on a cycle ergometer against given workloads (Bland, Pfeiffer, & Eisenmann, 2012). The heart rate (HR) responses to these workloads are recorded and P_{170} is calculated from the HR-workload linear relationship as the workload corresponding to 170 bpm. P_{170} is expressed in either absolute ($P_{170,abs}$, W) or relative to body mass values ($P_{170,rel}$, W.kg^{-1}). Aerobic capacity can be monitored by even more minimal equipment and expertise in the case of a step test, in which participants ascend and descend a step or box of a given height with a standard tempo dictated by a metronome. Among the various step test protocols, the YMCA step test has been used in dancers (Bronner & Rakov, 2014), basketball players (Nikolaidis, Calleja-González, & Padulo, 2014), non-athletes (Beutner et al., 2015; Jones, Coburn, Brown, & Judelson, 2012), and adults with intellectual disabilities (Pastula, Stopka, Delisle, & Hass, 2012).

Several studies have examined the relationship of the P_{170} and YMCA test with performance in a $VO2_{max}$ test enhancing our understanding of their validity and limitations (Boreham, Paliczka, & Nichols, 1990; Jankowski, Niedzielska, Brzezinski, & Drabik, 2015; Nikolaidis, 2011). However, whether the P_{170} and YMCA step test can be used interchangeably has not been examined yet. It would be of great practical importance for coaches and trainers if a step test could be used instead of the P_{170}, offering them a much more handy and inexpensive solution. Therefore, the aim of the present study was to examine the relationship between the YMCA step test and P_{170} in competitive female volleyball players.

Methods

Participants

The present investigation was conducted in two parts: the first was a cross-sectional study (n = 152, age 20.8±6.0 yrs, range 12.8-41.7 yrs, **Table 1**), and the second was a longitudinal study, in which a sub-group (n = 14, age 21.2±5.9 yrs, **Table 2**) of the first study was examined again for the same parameters exactly one year later. The first study was conducted on the preparation period of the 2014-2015 season, whereas the second study took place on the corresponding period of the 2015-2016 season. The adult participants (≥18 yrs age group, n = 87, age 24.8±5.4 yrs, range 18.2-41.7 yrs) competed with their teams in the top three national leagues of Greece and the adolescents (<18 yrs age group, n = 65, age 16.0±1.0 yrs, range 12.8-18.0 yrs) participated in the official tournaments of their age groups. The local institutional review board approved this study, which was conducted according to the ethical standards of Declaration of Helsinki of the World Medical Association in 1964 as it was modified in 2013. The participants provided informed consent.

Devices

An electronic body mass scale (HD-351 Tanita, Illinois, USA), a portable stadiometer (SECA, Leicester, UK) and a skinfold caliper (Harpenden, West Sussex, UK) were used to measure anthropometric characteristics (body mass, stature and skinfolds, respectively). Team2 Pro (Polar Electro Oy, Kempele, Finland) was used to record HR during all testing session. The P_{170} test was performed on a cycle ergometer (828 Ergomedic, Monark, Sweden). A box of 30 cm height was used in the YMCA step test.

Procedures

Before starting the testing session, the participants were examined for anthropometric characteristics. Body mass and stature were measured with participants being barefoot and in minimal clothing. These measurements were used to calculate Body mass index (BMI) as the quotient of body mass (kg) to stature squared (m^2). Body fat percentage (BF) was calculated from the sum of 10 skinfolds (Parizkova, 1978). Thereafter, the participants performed the P_{170} and YMCA step test in a counterbalanced order, separated by a 10 min break. In the P_{170} test, saddle height was adjusted to each participant's satisfaction and toe clips with straps were used to prevent the feet from slipping off the pedals. The participants were instructed to pedal with a steady cadence of 60 revolutions per minute, which was given by both audio (metronome set at 60 beats per minute) and visual means (ergometer's screen showing pedaling cadence). This test lasted 9 min including three 3 min stages, each against incremental braking force in order to elicit HR between 120 and 170 beats per minute (Bland et al., 2012). Between the two tests of aerobic capacity a break of passive recovery was provided. In the YMCA step test, the participants were instructed to ascend and descend a box for 3 min using a 24 ascent·min^{-1} cadence (Beutner et al., 2015). Two indices of this test were recorded: $Step_{end}$, the HR in the end of the test, and $Step_{rec}$, the HR in the end of the first minute of recovery. In the P_{170} test, the higher the $P_{170,abs}$ or $P_{170,rel}$, the higher the aerobic capacity, whereas in the YMCA step test, the lower the $Step_{end}$ or $Step_{rec}$, the higher the aerobic capacity.

The IBM SPSS v.20.0 (SPSS, Chicago, USA) software was used to perform the statistical analysis. Data were expressed as mean and standard deviations of the mean (SD). The differences between adolescent and adult participants were tested by an independent t-test, whereas a paired samples *t*-test compared the scores of the participants who were evaluated twice over a year. Mean differences together with 95% confidence intervals (CI) were calculated. The effect size for statistical differences in the t-test was interpreted by Cohen's *d* classified as $d \leq 0.2$, trivial; $0.2 < d \leq 0.6$, small; $0.6 < d \leq 1.2$, moderate; $1.2 < d \leq 2.0$, large; and $d > 2.0$, very large (Hopkins, Marshall, Batterham, & Hanin, 2009). Pearson correlation coefficient r examined the relationships among anthropometric characteristics and aerobic capacity tests, as well as the relationship among percentage changes in these tests over a year. To interpret the magnitude of correlations the following criteria were adopted: $r \leq 0.1$, trivial; $0.1 < r \leq 0.3$, small; $0.3 < r \leq 0.5$, moderate; $0.5 < r \leq 0.7$, large; $0.7 < r \leq 0.9$, very large; and $r > 0.9$, almost perfect (Hopkins et al., 2009). The level of significance was set at $\alpha=0.05$.

Results

The anthropometric characteristics of participants can be found in **Table 1**. Differences among age groups were shown for body mass and BF. The older age group (≥18 yrs) was heavier, but with less BF than the younger (<18 yrs) group ($p < 0.05$). These differences had small magnitude. The changes in anthropometric characteristics over a year can be seen in **Table 2**. Statistical differences were found for body mass and BF ($p < 0.05$). The magnitude of these changes was small.

Table 1. Anthropometric characteristics of volleyball players according to age group.

	<18 yrs (n=65)	>18 yrs (n=87)	Total (n=152)	Mean difference (95% CI)
Age (yrs)	16.0±1.0†	24.8±5.4†	20.8±6.0	–8.8 (–10.2; –7.5), d = –2.3
Body mass (kg)	62.7±7.3*	66.1±8.5*	64.7±8.2	–3.5 (–6.1; –0.9), d = –0.4
Height (cm)	170.3±6.1	172.5±7.3	171.6±6.9	–2.2 (–4.4;0.1), d = –0.3
BMI ($kg.m^{-2}$)	21.6±2.0	22.2±2.4	22.0±2.2	–0.6 (–1.3; 0.1), d = –0.3
BF (%)	24.6±4.1*	22.6±4.7*	23.5±4.5	2.0 (0.5;3.4), d = 0.5

BMI = body mass index, BF = body fat percentage, CI = confidence intervals, d = effect size Cohen's d;* and † significant difference between age groups at p<0.01 and p<0.001, respectively.

Table 2. Anthropometric characteristics of volleyball players in the longitudinal study.

	September 2014	September 2015	Mean difference (95% CI)
Age (yrs)	21.2±5.9†	22.2±5.9†	–1.0 (–1.0; –0.9), d = –0.2
Body mass (kg)	64.9±5.6*	65.9±5.7*	–1.0 (–1.9; –0.1), d = –0.2
Height (cm)	173.7±6.2*	174.2±6.3*	–0.1 (–0.8; –0.1), d = –0.3
BMI ($kg.m^{-2}$)	21.5±2.0	21.7±1.8	–0.2 (–0.5; 0.1), d = –0.1
BF (%)	23.6±4.8†	21.0±4.2†	2.6 (1.4;3.7), d = 0.6

BMI = body mass index, BF = body fat percentage, CI = confidence intervals, d = effect size Cohen's d;* and † significant difference within group at p<0.01 and p<0.001, respectively.

The results of the tests of the aerobic capacity for the cross-sectional study can be found in **Table 3**. The age groups differed for both tests and all indices ($p < 0.05$). In these tests, adult scored better than adolescent volleyball players. These differences were of moderate magnitude for $Step_{end}$, $P_{170,abs}$ and $P_{170,rel}$, and small for $Step_{rec}$. The changes in these tests over a year can be seen in **Table 4**. Except $Step_{end}$ (improvement of small magnitude, $p < 0.01$), no difference was observed the tests over a year.

Table 3. Aerobic capacity of volleyball players according to age group.

	Total (n=152)	<18 yrs (n=65)	≥18 yrs (n=87)	Mean difference (95% CI)
$P_{170,abs}$	142±38	125±30	153±39†	–28 (–40; –17), d = –0.8
$P_{170,rel}$	2.18±0.49	2.00±0.45	2.31±0.48†	–0.31 (–0.46; –0.16), d = –0.7
$Step_{end}$	152±15	158±13	148±15†	10 (6; 15) , d = 0.7
$Step_{rec}$	102±18	106±19	99±17*	7 (2; 13), d = 0.4

$P_{170,abs}$ = absolute physical working capacity at heart rate 170 bpm (W), $P_{170,rel}$ = relative physical working capacity at heart rate 170 bpm ($W.kg^{-1}$), $Step_{end}$ = heart rate in the end of the step test, $Step_{rec}$ = heart rate in the end of the first minute of recovery; the symbols * and † denoted significant difference between age groups at p<0.05 and p<0.001, respectively.

Table 4. Aerobic capacity of volleyball players in the longitudinal study (n = 14).

	September 2014	September 2015	Mean difference (95% CI)
$P_{170,abs}$	136±32	142±23	–6 (–22; 10), d = –0.2
$P_{170,rel}$	2.10±0.49	2.17±0.36	–0.07 (–0.31; 0.17), d = –0.2
$Step_{end}$	155±17	146±12*	9 (2; 16) , d = 0.6
$Step_{rec}$	104±19	96±12	9 (–2; 20), d = 0.5

$P_{170,abs}$ = absolute physical working capacity at heart rate 170 bpm (W), $P_{170,rel}$ = relative physical working capacity at heart rate 170 bpm ($W.kg^{-1}$), $Step_{end}$ = heart rate in the end of the step test, $Step_{rec}$ = heart rate in the end of the first minute of recovery; the symbol * denoted significant difference within group at p<0.05.

The correlations among anthropometric characteristics and indices of aerobic capacity can be seen in **Table 5.** All indices of aerobic capacity correlated with age in the older group and in the total sample ($p < 0.05$), i.e. the older the age, the better the performance. $P_{170,rel}$ in the total sample and step test indices in the adult group and in the total sample correlated negatively with BF ($p < 0.05$), i.e. the higher the BF, the lower the performance. However, body mass, height and BMI correlated only with $P_{170,abs}$ ($p < 0.05$).

Table 5. Correlations among aerobic capacity tests in volleyball players.

	$P_{170,abs}$			$P_{170,rel}$			$Step_{ex}$			$Step_{rec}$		
	Total	<18 yrs	≥18 yrs	Total	<18 yrs	≥18 yrs	Total	<18 yrs	≥18 yrs	Total	<18 yrs	≥18 yrs
Age	0.42‡	-0.01	0.30†	0.37‡	0.02	0.30†	-0.45‡	-0.20	-0.42‡	-0.23†	-0.03	-0.21
Body mass	0.52‡	0.33†	0.56‡	0.06	-0.16	0.10	-0.08	0.09	-0.07	-0.08	-0.03	-0.04
Height	0.35‡	0.21	0.37‡	0.08	-0.10	0.10	-0.05	0.18	-0.08	-0.03	0.09	-0.06
BMI	0.36‡	0.26*	0.38‡	0.02	-0.13	0.04	-0.06	-0.03	-0.01	-0.08	-0.12	-0.01
BF	0.03	0.11	0.12	-0.21†	-0.17	-0.15	0.26†	0.11	0.25*	0.20*	0.06	0.24*

BMI = body mass index, BF = body fat percentage, $P_{170,abs}$ = absolute physical working capacity at heart rate 170 bpm (W), $P_{170,rel}$ = relative physical working capacity at heart rate 170 bpm ($W.kg^{-1}$), $Step_{end}$ = heart rate in the end of the step test, $Step_{rec}$ = heart rate in the end of the first minute of recovery. The symbols *, † and ‡ denoted significance at p<0.05, p<0.01 and p<0.001, respectively.

With regards to the correlations between the two tests of aerobic capacity (**Table 6**), the YMCA step test correlated largely ($Step_{rec}$) and very largely ($Step_{end}$) with $P_{170,rel}$, and with large correlations with $P_{170,abs}$ ($p < 0.001$). Regression equations between step test and P_{170} indices can be seen in **Figure 1**. The standard error of estimate of $Step_{rec}$ was higher than $Step_{end}$ for both $P_{170,abs}$ and $P_{170,rel}$.

Table 6. Correlations among aerobic capacity indices in volleyball players.

	$P_{170,abs}$			$P_{170,rel}$		
	<18 yrs	≥18 yrs	Total	<18 yrs	≥18 yrs	Total
$Step_{end}$	-0.66*	-0.62*	-0.68*	-0.76*	-0.71*	-0.76*
$Step_{rec}$	-0.51*	-0.51*	-0.54*	-0.54*	-0.58*	-0.58*

$P_{170,abs}$ = absolute physical working capacity at heart rate 170 bpm (W), $P_{170,rel}$ = relative physical working capacity at heart rate 170 bpm ($W.kg^{-1}$), $Step_{end}$ = heart rate in the end of the step test, $Step_{rec}$ = heart rate in the end of the first minute of recovery. The symbol * denoted significance at p<0.001.

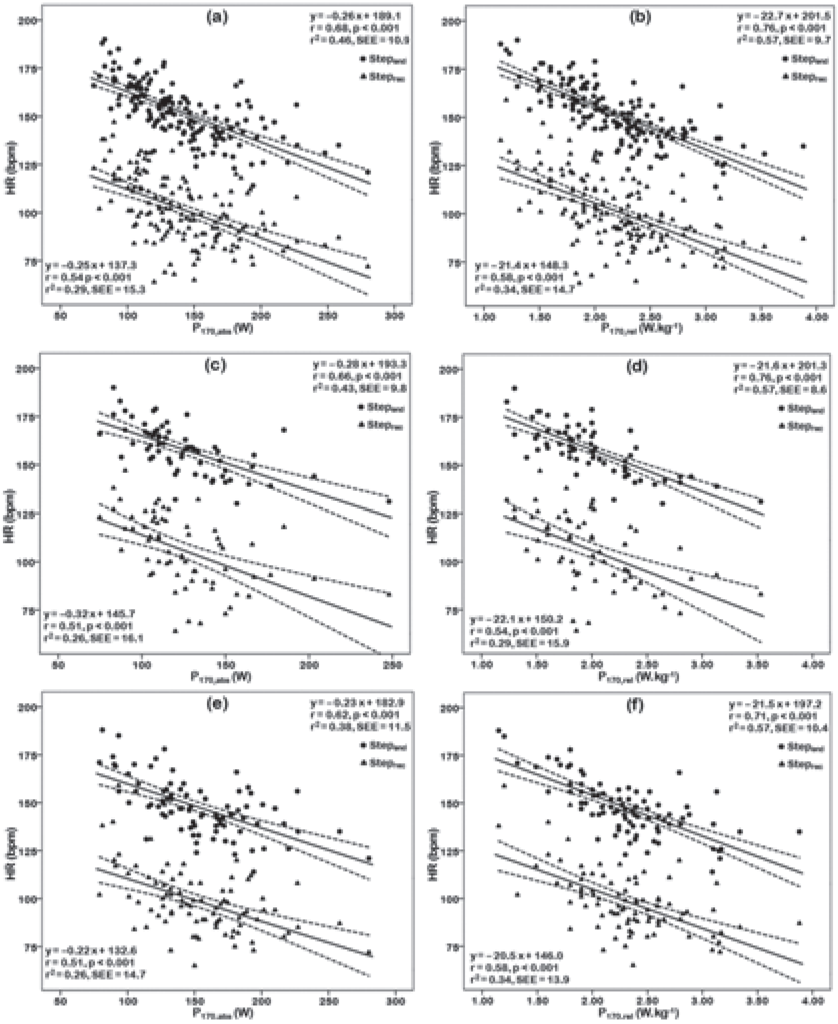

Figure 1. The relationship of $Step_{end}$ and $Step_{rec}$ with $PWC_{170,abs}$ and $PWC_{170,rel}$ in the total sample (a, b), adolescent (c,d) and adult volleyball players (e,f), respectively.

Discussion

To study the relationship between the YMCA step test and the P170 test, and the variation of this relationship by age, female adolescent and adult volleyball players performed these two tests. The main findings of the present study were that (a) the YMCA step test correlated largely ($Step_{rec}$) and very largely ($Step_{end}$) with P_{170}, (b) the magnitude of these correlations was higher in $P_{170,rel}$ than in $P_{170,abs}$, (c) these correlations were larger in adult than in adolescent volleyball players, and

(d) paradoxically, a trend of increase in aerobic capacity with age in the adult group was observed.

The larger correlation of P_{170} with $Step_{end}$ than with $Step_{rec}$ should be expected, because P_{170} and $Step_{end}$ reflected HR responses to exercise, whereas $Step_{rec}$ represented the function of recovery. The larger correlations of the YMCA step test with $P_{170,rel}$ than with $P_{170,abs}$ might be explained taking into account the role of body mass. In the cycle ergometer, a large body mass was compensated by the fact that the test was conducted with the participant supported by the seat; on the other hand, in the step test, the body mass was an important factor that the participant had to carry in the step (Saint-Maurice et al., 2014). Hence, when the P170 was expressed in relative values was logical that the correlation should be larger. As it was shown in the correlation analysis between anthropometric characteristics and aerobic capacity, there was a moderate to large correlation between body mass and $P_{170,abs}$, i.e. the higher the body mass, the higher the $P_{170,abs}$.

The performance in the aerobic tests low to moderately correlated with age, i.e. the older the age, the better the performance, whereas no correlation was observed in the adolescent group. The finding in the younger group was in agreement with the existing literature, where aerobic capacity remained relatively stable from 12 to 18 yrs in females (Shvartz & Reibold, 1990; Nikolaidis et al., 2012). However, the finding in the older group was not in line with the existing literature (Fitzgerald, Tanaka, Tran, & Seals, 1997; Grigaliuniene et al., 2013; Shvartz & Reibold, 1990), which has clearly demonstrated that aerobic capacity declined after the age of 18 years in women (independently of the training status). For example, a meta-analysis of sedentary, active and endurance-trained female adults showed that maximal aerobic capacity declined with increasing age (Fitzgerald et al., 1997). Compared to a 20-29 yrs age group, women of 30-39 yrs showed lower VO_{2max} and HR_{max} (Grigaliuniene et al., 2013). A review on aerobic capacity norms showed that females had VO_{2max} 1.8, 2.2, 1.8 $L.min^{-1}$ at the age of 12, 18 and 30 yrs, respectively (Shvartz & Reibold, 1990).

The significant correlation of aerobic capacity with age in the adults might be interpreted in three ways. First, a better aerobic capacity in the older group might result from the long-term training process in volleyball, where athletes with lower capacity would not advance. Second, both tests used in the present study were based on HR responses to a given submaximal load. A negative effect of age on maximal HR (HR_{max}) has been well-established previously, and consequently HR_{max} could be predicted by age-based equations (e.g. Tanaka's 208−0.7×age). The adolescent and adult groups differed by ~9 yrs and had predicted HR_{max} 197 and 191 bpm, respectively. Consequently, the HR responses to the 3-min step test were quite similar when being expressed as $\%HR_{max}$ (80 *versus* 78%, respectively). Even if the 3-min step test elicited different HR responses, it caused similar relative physiological load in both age groups. The third one explained this correlation between age and aerobic capacity since a correct training, based on long distance and low intensity or short distance and high intensity, could revert the effects traditionally associated with age, according to actually studies conducted not only in <30 years athletes, but also in adults and elderly people (Broman, Quintana, Lindberg, Jansson, & Kaijser, 2006; Clemente-Suarez, 2014). This might be a reasonable explanation of the paradox of better aerobic capacity in the older volleyball players.

A limitation of the present study was that its longitudinal part did not include more testing in more periods of the season (e.g. beginning *versus* end of preparation period); thus, there were very small changes in the two aerobic capacity tests and, consequently, this might be a reason that the correlation analysis could not identify any relationship between the two tests over time. On the other hand, strength of this study was that it included one of the largest samples of female volleyball players ever studied, which allowed drawing inferences for other groups of volleyball players, too. Moreover, these findings might be of great practical value for volleyball coaches and trainers in the context of monitoring aerobic capacity of their athletes.

Practical Applications

Specific evaluation is very important for the coaches and trainers. This study is of great practical importance for coaches and trainers a step test could be used instead of the P170, offering them a much more handy and inexpensive solution. Based on the findings of the present study, it was concluded that the YMCA step test (especially the $Step_{end}$ index) and P_{170} might be used interchangeably by coaches and trainers to monitor aerobic capacity of female volleyball players.

Conclusions

Based on the findings of the present study, it was concluded that the YMCA step test and P_{170} might be used interchangeably by coaches and athletes to monitor aerobic capacity of female volleyball players. Instead of $Step_{rec}$, $Step_{end}$ should be preferred as a better proxy for P_{170}. Since both tests relied on HR response to exercise – and HR was influenced by age, they should be used to monitor aerobic capacity only within short ranges of age.

References

1. Beutner, F., Ubrich, R., Zachariae, S., Engel, C., Sandri, M., Teren, A., & Gielen, S. (2015). Validation of a brief step-test protocol for estimation of peak oxygen uptake. *European Journal of Preventive Cardiology, 22*(4), 503-512. doi: 10.1177/2047487314533216
2. Bland, J., Pfeiffer, K., & Eisenmann, J. C. (2012). The PWC170: Comparison of diVerent stage lengths in 11-16 year olds. *European Journal of Applied Physiology, 112*(5), 1955-1961. doi: 10.1007/s00421-011-2157-z
3. Boreham, C. A. G., Paliczka, V. J., & Nichols, A. K. (1990). A comparison of the PWC170 and 20-MST tests of aerobic fitness in adolescent schoolchildren. *Journal of Sports Medicine and Physical Fitness, 30*(1), 19-23.
4. Broman, G., Quintana, M., Lindberg, T., Jansson, E., & Kaijser, L. (2006). High intensity deep water training can improve aerobic power in elderly women. *European Journal of Applied Physiology, 98*(2), 117-123.
5. Bronner, S., & Rakov, S. (2014). An accelerated step test to assess dancer pre-season aerobic fitness. *Journal of dance medicine & science : official publication of the International Association for Dance Medicine & Science, 18*(1), 12-21. doi: 10.12678/1089-313X.18.1.12
6. Clemente-Suarez, V.J. (2014). Changes in Biochemical, Strength, Flexibility, and Aerobic Capacity Parameters after a 1700 km Ultraendurance Cycling Race. *Biomed Res Int, Article ID 602620*.
7. Dávila-Romero, C., Hernández-Mocholí, M. A., & García-Hermoso, A. (2015). Technical player profiles related to the physical fitness of young female volleyball players predict team performance. *Journal of Sports Medicine and Physical Fitness, 55*(3), 137-143.
8. Ekblom, Ö. (2014). Testing the validity of three submaximal ergometer tests for estimating maximal aerobic capacity in children. *Acta paediatrica (Oslo, Norway : 1992), 103*(5), 559-563. doi: 10.1111/apa.12582
9. Fitzgerald, M. D., Tanaka, H., Tran, Z. V., & Seals, D. R. (1997). Age-related declines in maximal aerobic capacity in regularly exercising vs. sedentary women: a meta-analysis. *Journal of Applied Physiology (1985), 83*(1), 160-165.
10. Grigaliuniene, A., Ramonas, A., Celutkiene, J., Sileikiene, V., Rudys, A., Juocevicius, A., & Laucevicius, A. (2013). Cardiorespiratory parameters of exercise capacity in a healthy Lithuanian population: the pilot study. *Hellenic J Cardiol, 54*(2), 107-118.
11. Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41*(1), 3-13. doi: 10.1249/MSS.0b013e31818cb278
12. Jankowski, M., Niedzielska, A., Brzezinski, M., & Drabik, J. (2015). Cardiorespiratory fitness in children: a simple screening test for population studies. *Pediatric Cardiology, 36*(1), 27-32. doi: 10.1007/s00246-014-0960-0
13. Jones, L. A., Coburn, J. W., Brown, L. E., & Judelson, D. A. (2012). Effects of static stretching on heart rate and fitness classification following the YMCA step test. *Gazzetta Medica Italiana Archivio per le Scienze Mediche, 171*(5), 613-620.
14. Laporta, L., Nikolaidis, P., Thomas, L., & Afonso, J. (2015). Attack Coverage in High-Level Men's Volleyball: Organization on the Edge of Chaos? *Journal of Human Kinetics, 47*(1), 249-257. doi: 10.1515/hukin-2015-0080
15. Mahar, M. T., Guerieri, A. M., Hanna, M. S., & Kemble, C. D. (2011). Estimation of aerobic fitness from 20-m multistage shuttle run test performance. *American Journal of Preventive Medicine, 41*(4 Suppl 2), S117-123. doi: 10.1016/j.amepre.2011.07.008
16. Nikolaidis, P. (2011). Association between submaximal and maximal measures of aerobic power in female adolescents. *Biomedical Human Kinetics, 3*, 106-110. doi: 10.2478/v10101-011-0023-4
17. Nikolaidis, P., Calleja-González, J., & Padulo, J. (2014). The effect of age on positional differences in anthropometry, body composition, physique and anaerobic power of elite basketball players. *Sport Sciences for Health, 10*(3), 225-233. doi: 10.1007/s11332-014-0198-5
18. Nikolaidis, P.T., Ziv, G., Arnon, M., & Lidor, R. (2012). Physical characteristics and physiological attributes of female volleyball players-the need for individual data. *Journal of Strength and Conditioning Research, 26* (9), 2547-2557. doi: 10.1519/JSC.0b013e31823f8c06
19. Parizkova, J. (1978). Lean body mass and depot fat during autogenesis in humans. In J. Parizkova & V. Rogozkin (Eds.), *Nutrition, Physical Fitness and Health: International Series on Sport Sciences*. Baltimore: University Park Press.
20. Pastula, R. M., Stopka, C. B., Delisle, A. T., & Hass, C. J. (2012). Effect of moderate-intensity exercise training on the cognitive function of young adults with intellectual disabilities. *Journal of Strength and Conditioning Research, 26*(12), 3441-3448. doi: 10.1519/JSC.0b013e318270fc83
21. Saint-Maurice, P. F., Welk, G. J., Laurson, K. R., & Brown, D. D. (2014). Measurement agreement between estimates of aerobic fitness in youth: the impact of body mass index. *Research Quarterly in Exercise and Sport, 85*(1), 59-67. doi: 10.1080/02701367.2013.872217
22. Sheppard, J.M., Gabbett, T.J., & Stanganelli, L.C.R. (2009). An analysis of playing positions in elite men's volleyball: considerations for competition demands and physiologic characteristics. *Journal of Strength and Conditioning Research, 23*(6), 1858-1866.
23. Shvartz, E., & Reibold, R. C. (1990). Aerobic fitness norms for males and females aged 6 to 75 years: a review. *Aviation, Space and Environmental Medicine, 61*(1), 3-11.