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Original empirical article

POSTURAL SWAY AND CARDIORESPIRATORY RESPONSE TO RESISTANCE EXERCISES

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Abstract. *The study compares parameters of balance after different forms of resistance exercise and after voluntary hyperventilation. A group of 22 physical education students performed 20 squats, calf raises, biceps curls, and presses behind the neck with an additional load of 50 % 1 RM. Besides this, they hyperventilated for a time corresponding to the duration of the exercises. Thirty seconds prior to and two minutes after the exercises the velocity of the centre of pressure was registered at 100 Hz by means of a posturography system FiTRO Sway Check based on force platform. While exercising and standing on the platform, parameters of ventilation and heart rate were continuously monitored using a breath-by-breath system MMC Horizon Sensormedics. The results showed the highest increase in velocity of the centre of pressure after squats (16.4 ± 1.4 mm/s), followed by calf raises (15.2 ± 1.3 mm/s), voluntary hyperventilation (14.8 ± 1.2 mm/s), biceps curls (14.0 ± 1.1 mm/s), and presses behind the neck (13.6 ± 0.8 mm/s). Similarly, the highest ventilation was found after squats (59.1 ± 6.6 l/min), then after calf raises (48.2 ± 5.8 l/min), voluntary hyperventilation (44.1 ± 5.2 l/min), biceps curls (40.0 ± 4.6 l/min), and presses behind the neck (38.9 ± 3.8 l/min). In addition, the heart rate was the highest after squats (165.0 ± 7.2 beats/min), following by calf raises (135.0 ± 6.8 beats/min), biceps curls (129.2 ± 5.8 beats/min), presses behind the neck (125.1 ± 4.6 beats/min), and voluntary hyperventilation (117.2 ± 4.8 beats/min). Furthermore, a significant ($p \leq 0.01$) increase to a pre-exercise level in all of the parameters (8.6 ± 0.2 mm/s, 12.3 ± 0.1 l/min, and 76.5 ± 1.8 beats/min, respectively) has been found. During the phase of recovery, there was a close correlation between sway velocity and ventilation after squats (r = 0.939), calf raises (r = 0.919), biceps curls (r = 0.896), and presses behind the neck (r = 0.889). It may be concluded that a more marked ventilation rather than fatigue is responsible for an impairment of balance after resistance exercises.*

Key words: *Fatigue, hyperventilation, postural stability, resistance exercises*

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INTRODUCTION

Several studies have documented that various forms of exercise, such as running (Lepers et al, 1997; Derave et al., 2002; Zemkova et al., 2005/a), cycling (Seliga et al., 1991; Nardone et al., 1997; Zemkova et al., 2005/a), walking (Hashiba, 1998; Nardone et al., 1998), as well as repeated jumps (Zemkova et al., 2005/b) or calf raises (Lundin et al., 1993; Yaggie & McGregor, 2002; Zemkova et al., 2005/b) and sustaining a stance on tiptoes (Vuillerme et al., 2002) adversely affect postural stability.

Fatigue has been proposed as a principal factor responsible for such an impairment of balance. However, this effect is usually a consequence of prolonged exercise, as shown by Lepers et al. (1997) after 25 km running and 1 h 44 min cycling, Derave et al. (2002) after 30 min of treadmill walking and running, and Zemkova & Hamar (2004) after 45 min of cycling at moderate intensity.

In fact, after short-term, highly intensive exercise on the cycle ergometer, a level of ventilation has been found closely correlated to sway velocity (Zemkova & Hamar, 2003) indicating that recovery hyperventilation should be considered as an important factor in post-exercise balance impairment.

On the other hand, there is a lack of information about how this factor influences balance after resistance exercises, inducing not only fatigue of the muscle groups involved but also increasing ventilation. Based on results of our previous study (Zemkova & Hamar, 2005) which showed that hyperventilation was responsible for balance impairment after short-term isokinetic cycling, it may be assumed that its contribution to the deterioration of postural stability after resistance exercises might also be more significant than the fatigue reported by above-mentioned authors (Lundin et al., 1993; Yaggie & McGregor, 2002; Vuillerme et al., 2002).

Therefore, the aim of the study was to compare the parameters of balance after different forms of resistance exercise and after voluntary hyperventilation.

METHODS

Subjects

A group of 22 physical education students (age 21.2 ± 2.1 years, height 178.2 ± 4.4 cm, weight 73.6 ± 9.4 kg) volunteered to participate in the study. All of them were informed of the procedures and of the main purpose of the study.

Test protocol

The subjects performed 20 squats, calf raises, biceps curls, and presses behind the neck with an additional load of 50 % 1 RM. In addition to this, they hyperventilated for a time corresponding to the duration of the exercises.

Thirty seconds prior to and two minutes after the exercises, the velocity of the centre of pressure (COP) was registered. Subjects were instructed to minimize postural sway by standing as still as possible.

While exercising and standing on a stabilographic platform, the parameters of ventilation and heart rate were continuously monitored.

A subjective level of exertion was estimated at the end each exercise using Borg's 6 to 20 Rating of Perceived Exertion Scale (Borg, 1970).

Diagnostic equipment

Basic stabilographic parameters (e.g., COP velocity) were registered at 100 Hz by means of the posturography system FiTRO Sway Check based on a force platform (www.fitronic.sk). Subjects stood barefoot with feet 10 cm apart. They were instructed to minimize postural sway by standing as still as possible. The average values of 5-second intervals were used for the evaluation.

Cardiorespiratory parameters were monitored using a breath-by-breath system MMC Horizon Sensormedics.

Statistical analysis

Ordinary statistical methods including average, standard deviation, and coefficient of correlation were used. A paired t-test was employed to determine the statistical significance of the differences between pre- and post-exercise values of the parameters of balance, ventilation and heart rate, and a level of $p < 0.05$ was considered significant.

RESULTS

The results showed (Figure 1) a highest increase in velocity of the centre of pressure after squats (16.4 ± 1.4 mm/s), followed by calf raises (15.2 ± 1.3 mm/s), voluntary hyperventilation (14.8 ± 1.2 mm/s), biceps curls (14.0 ± 1.1 mm/s), and presses behind the neck (13.6 ± 0.8 mm/s).

In all cases a predominant shift in the medio-lateral (10.1 mm/s, 9.3 mm/s, 8.5 mm/s, 8.2 mm/s) rather than the antero-posterior direction (6.3 mm/s, 5.9 mm/s, 5.5 mm/s, 5.4 mm/s) was found.

Similarly, the highest ventilation (Figure 2) was found after squats (59.1 ± 6.6 l/min), then after calf raises (48.2 ± 5.8 l/min), voluntary hyperventilation (44.1 ± 5.2 l/min), biceps curls (40.0 ± 4.6 l/min), and presses behind the neck (38.9 ± 3.8 l/min).

In addition, heart rate (Figure 3) was the highest after squats (165.0 ± 7.2 beats/min), following by calf raises (135.0 ± 6.8 beats/min), biceps curls (129.2 ± 5.8 beats/min), presses behind the neck (125.1 ± 4.6 beats/min), and voluntary hyperventilation (117.2 ± 4.8 beats/min).

In all of the parameters a significant ($p \leq 0.01$) increase to the pre-exercise level has been found (8.6 ± 0.2 mm/s, 12.3 ± 0.1 l/min, and 76.5 ± 1.8 beats/min, respectively).

In phase of recovery, there was a close correlation between sway velocity and ventilation after squats ($r = 0.939$), calf raises ($r = 0.919$), biceps curls ($r = 0.896$), and presses behind the neck ($r = 0.889$).

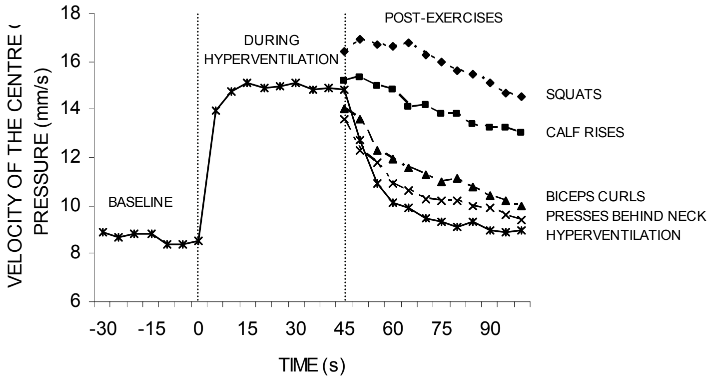

Fig. 1. Velocity of the centre of pressure prior to and after resistance exercises and voluntary hyperventilation.

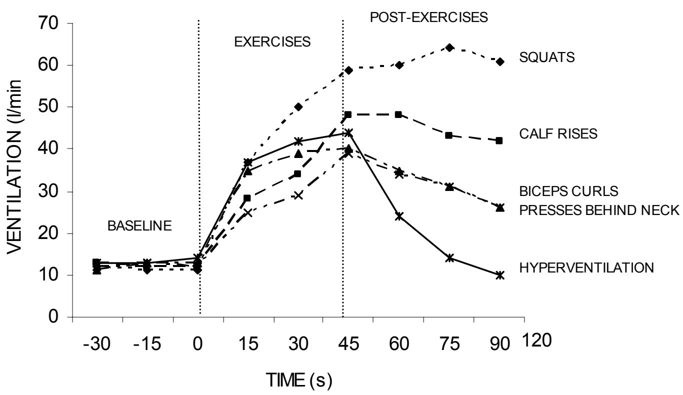

Fig. 2. Ventilation before, during and after resistance exercises and voluntary hyperventilation.

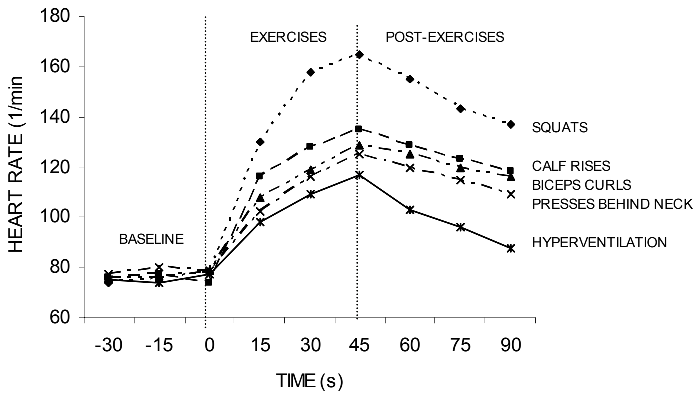

Fig. 3. Heart rate before, during and after resistance exercises and voluntary hyperventilation.

DISCUSSION

Impairment of postural stability in the early phase of recovery after resistance exercises is quite probably due to more pronounced ventilation. This assumption may be corroborated by the close correlation between level of ventilation and sway velocity during the recovery phase.

In addition, sway velocity after voluntary hyperventilation having reached a maximum at the end of exercise, started to decline immediately during the recovery phase. On the other hand, its values after resistance exercises, particularly after those performed with lower extremities, remained temporarily elevated and only after about 25 and 10 seconds a gradual decrease back to the resting level set in. Though this effect may be mainly a consequence of delayed activation of ventilation during an early phase of recovery after such exercises, the contribution of fatigue cannot be excluded.

However, this finding is not in agreement with the studies of several authors (e.g., Lundin et al., 1993; Yaggie & McGregor, 2002; Vuillerme et al., 2002) who attributed post-exercise impairment of balance mainly to fatigue. In contrast, Adlerton & Moritz (1996) showed that calf muscle fatigue, induced by maximal repeated heel raises, does not affect balance. Corbeil et al. (2003) have found that such a localized muscular fatigue more profoundly affects motor output of the postural control than the sensory system, and despite some changes in balance, the sensorimotor system is rather efficient at maintaining stability during fatigue. It has been suggested that compensatory mechanisms, e.g., increased reflex activity in muscle spindles (Nelson & Hutton, 1985) and increased muscle stiffness (Winter et al., 1998) are involved in postural control during fatigue.

Unfortunately, the intended evaluation of fatigue by Borg´s scale of perceived exertion (Borg, 1970) could not be applied in this study because contradictory results were noted. Subjects familiarized with strength training reported lower levels of fatigue as compared to those accustomed to other sport activities. In addition, they perceived a relatively high level of fatigue after exercises performed with smaller muscle groups, which is in contrast with lower values of sway velocity, as compared to those performed with larger muscle groups (e.g., biceps curls and squats).

From practical point of view, it should be confusing for the elderly and individuals with coordination problems. In spite of the low level of perceived fatigue after such exercises, their postural stability could be more profoundly impaired, which might result in a subsequent decrease. Therefore, further studies are needed to elaborate on the recommendations and design of specific exercise programs for these individuals.

It should also be taken in account that postural sway response to resistance exercise depends not only on the type of exercise but also on its intensity (additional weight or rate of movement), the activated muscle mass, the number of repetitions and sets. It may be documented by our preliminary results which show an increase in velocity of the centre of pressure and ventilation as the additional load, reps, sets, and rate of movement increased. However, it remains for us to ascertain even more precisely the contribution of ventilation and fatigue on the post-exercise deterioration of balance not only under static but also under dynamic conditions, e.g. using dynamic posturography systems or 3D biomechanical analysis (Psalman, 2008).

CONCLUSION

Impairment of balance in an early phase of recovery after resistance exercises is a consequence of more marked ventilation rather than of fatigue. This effect is more evident after exercises performed with the lower (squats and calf raises) rather than the upper extremities (biceps curls and presses behind neck).

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IZMENE U TEŽIŠTU TELA I KARDIO-RESPIRATORNI ODGOVOR NA TRENIRANJE SA DOZIRANIM OPTEREĆENJEM

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Ovo istraživanje poredi parametre održavanja ravnoteže nakon različitih vrsti treniranja sa opterećenjem i nakon hiperventilacije. Ukupno 22 studenta fizičkog vaspitanja radilo je 20 čučnjeva, istezanje listova, vežbe za bicepse i potisak iza vrata sa dodatnim optrećenjem od 50 % 1 RM. Pored toga, podvrgli su se hiperventilaciji koja je trajala koliko i vežbe. Trideset sekundi pre i dva minuta nakon vežbi brzina težišta tela merena je na 100 Hz uz pomoć FiTRO Sway Check sistema za merenje držanja tela koji se bazira na platformi za delovanje sile. Dok su vežbali i stajali na platformi, parametri za ventilaciju i brzina otkucaja srca su se neprekidno merili uz pomoć dah-po-dah MMC Horizon Sensormedics sistema. Rezultati su pokazali da je porast sile težišta tela najveći nakon čučnjeva (16.4 ± 1.4 mm/s), zatim istezanja listova (15.2 ± 1.3 mm/s), hiperventilacije (14.8 ± 1.2 mm/s), vežbi za bicepse (14.0 ± 1.1 mm/s), i potiska iza vrata (13.6 ± 0.8 mm/s). Takođe, najveće vrednosti hiperventilacije zabeležene su nakon čučnjeva (59.1 ± 6.6 l/min), zatim nakon istezanja listova (48.2 ± 5.8 l/min), hiperventilacije (44.1 ± 5.2 l/min), vežbi za bicepse (40.0 ± 4.6 l/min), i potiska iza vrata (38.9 ± 3.8 l/min). Pored toga, brzina otkucaja srca bila je najveća nakon čučnjeva ats (165.0 ± 7.2 beats/min), zatim istezanja listova (135.0 ± 6.8 beats/min), vežbi za bicepse (129.2 ± 5.8 beats/min), potiska iza vrata (125.1 ± 4.6 beats/min), i hiperventilacije (117.2 ± 4.8 beats/min). Dalje, značajan porast ($p \leq 0.01$) na nivo pre početka vežbanja je utvrđen za sve parametre (8.6 ± 0.2 mm/s, 12.3 ± 0.1 l/min, i 76.5 ± 1.8 otkucaja/min, tim redosledom). Tokom faze oporavka, javila se jaka korelacija između brizine izmene težišta tela i ventilacije nakon čučnjeva ($r = 0.939$), istezanja listova ($r = 0.919$), vežbi za bicepse ($r = 0.896$), i potiska iza vrata ($r = 0.889$). Možemo zaključiti da je jača ventilacija pre nego umor odgovorna za poteškoće u očuvanju težišta tela nakon trenirana sa opterećenjem.

Ključne reči: *umor, hiperventilacija, stabilno držanje tela, vežbe sa opterećenjem*