"ALL-OUT" TETHERED RUNNING AS AN ALTERNATIVE TO WINGATE ANAEROBIC TEST

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Abstract:

An "all-out" tethered running on the treadmill represents an alternative form of exercise used for the assessment of anaerobic capacity. Contrary to the well known and frequently used "all-out" test on the cycle ergometer (Wingate anaerobic test), there is a lack of information concerning the parameters of anaerobic capacity obtained from tethered running on the treadmill. The aim of our study was therefore to compare the parameters of anaerobic capacity (maximal and mean power, fatigue index, and blood lactate concentration) in 30-second "all-out" tests performed on the isokinetic cycle ergometer and in the form of tethered running on the treadmill, respectively. The subjects underwent in random order in two different days a period of 30-second "all-out" cycling on the isokinetic ergometer at a revolution rate of 100 rpm and tethered running on the treadmill at a velocity of 13 km/h. Analyses of the results showed that tethered running and isokinetic cycling did not differ significantly either in maximal or mean power. However, the fatigue index and blood lactate were significantly higher in tethered running than in isokinetic cycling. Taking into account the similar values of maximal and mean power production between the exercise modes examined it may be concluded that the 30-second "all-out" tethered running on the treadmill represents an acceptable alternative for the assessment of anaerobic capacity. However, in comparison with isokinetic cycling slightly higher values of fatigue index and blood lactate have to be expected.

Keys words: *anaerobic capacity, cycling on the isokinetic ergometer, tethered running on the treadmill, Wingate anaerobic test*

MAXIMALES DEN WIDERSTAND ÜBERWINDENDES LAUFEN ALS EINE ALTERNATIVE DES WINGATE ANAEROBEN TESTS

Zusammenfassung:

Maximales den Widerstand überwindendes Laufen auf dem Laufband repräsentiert eine Alternativ-Belastung für die Diagnostik anaerober Leistungsfähigkeit. Im Vergleich zu dem bekannten und oft benutzten *all-out* Test am Fahrradergometer (Wingate test), gibt es über die Parameter, die bei so einem anaeroben Testverfahren behoben werden, nur ungenügende Informationen. In dieser Arbeit werden die Parameter anaerober Leistungsfähigkeiten (maximale und durchschnittliche Schnellkraft, Ermüdungsindex und Blutlaktat nach der Belastung), die bei der 30-sekündlichen maximalen Belastung am isokinetischen Fahrradergometer und bei dem den Widerstand überwindenden Laufen am Laufband ermittelt wurden, mit jenen vom Fahrradergometer-Test verglichen. Eine Gruppe von 17 Sportlern hat in einer zufälliger Reihenfolge in zwei unterschiedlichen Tagen eine 30-sekündliche maximale Belastung am isokinetischen Fahrradergometer (Trittfrequenz von 100 Umdrehungen pro Minute) und maximales den Widerstand überwindendes Laufen am Laufband (Geschwindigkeit von 13 $km \cdot h^{-1}$) absolviert. Die Korrelationskoeffiziente zeigten einen engen Zusammenhang zwischen den Parametern von beiden Tests. Es wurden auch keine statistisch signifikante Unterschiede zwischen der durchschnittlichen und maximalen Schnellkraft während beider Belastungsformen ermittelt, allerdings der Ermüdungsindex und der Blutlaktat nach der Belastung waren signifikant höher ($P<0,05$) bei der Belastung am Laufband als am Fahrradergometer. Aufgrund ähnlicher Werte durchschnittliche und maximaler Schnellkraft bei den beiden Belastungsformen kann das 30-sekündliche maximale den Widerstand überwindende Laufen auf dem Laufband als eine akzeptable Alternative für Diagnostik von anaerober Leistungsfähigkeit betrachtet werden. Allerdings im Vergleich zu dem Fahrradergometertest sollten ein bisschen höhere Werte des Ermüdungsindex und des Blutlaktats erwartet werden.

Schlüsselwörter: *anaerobe Leistungsfähigkeit, Belastung auf dem isokinetischen Fahrradergometer, maximales den Widerstand überwindendes Laufen, Wingate Test*

Introduction

An "all-out" load on the cycle ergometer, either in a revolution-dependent (Wingate anaerobic test) or an isokinetic mode, represents a typical form of exercise used for the laboratory assessment of anaerobic capacity. On the other hand, for many sports pedalling does not provide a really specific form of muscle activity. For most of the weight-bearing acti-vities running seems to be the more appro-priate alternative. However, with simple tre-admill running it is practically not feasible to implement a time limited "all-out" task. This drawback can be avoided by modified activity termed *tethered running,* during which the subject in addition to running, pulls a rope attached to a waist belt and the wall behind the treadmill (Hamar, 1999). A simple computer-based system can be employed to register the drag force, running velocity and to calculate the manifested running power. Data collected reveal the stride-dependent fluctuation of force and power over time and enable the calculation of peak as well as average values of force and power for a specific period. Repeated short-term "all-out" bouts (5 to 10 seconds) of tethered running at different velocities provide data, which can be used for the construction of individual force-velocity and power-velocity curves. Similarly to other types of muscle activity there is a decline of integrated force with increased velocity. On the other hand, integrated power increases from lower velocities, reaches a maximum, and then, towards higher velocities, declines again. Maximal drag power and corresponding velocity can be derived from such a curve (Hamar, Baron, Bachl, Tschan, Tkáč, Kampmiller, & Komadel, 1992). Thus, such a 30-second "all-out" exercise as an analogue of Wingate anaerobic test (Ayalon, Inbar, & Bar-Or, 1974; Bar-Or, 1981; Bar-Or, 1987) providing maximal and mean power, allows the fatigue index to be calculated.

However, contrary to the well known and frequently used "all-out" test on the cycle ergometer, there is a lack of information concerning the parameters of anaerobic capacity obtained from tethered running on the treadmill. The aim of our study was therefore to compare the parameters of anaerobic capacity (maximal and mean power, fatigue index, and blood lactate concentration) in 30-second "all-out" tests performed on the isokinetic cycle ergometer and in the form of tethered running on the treadmill, respectively.

Methods

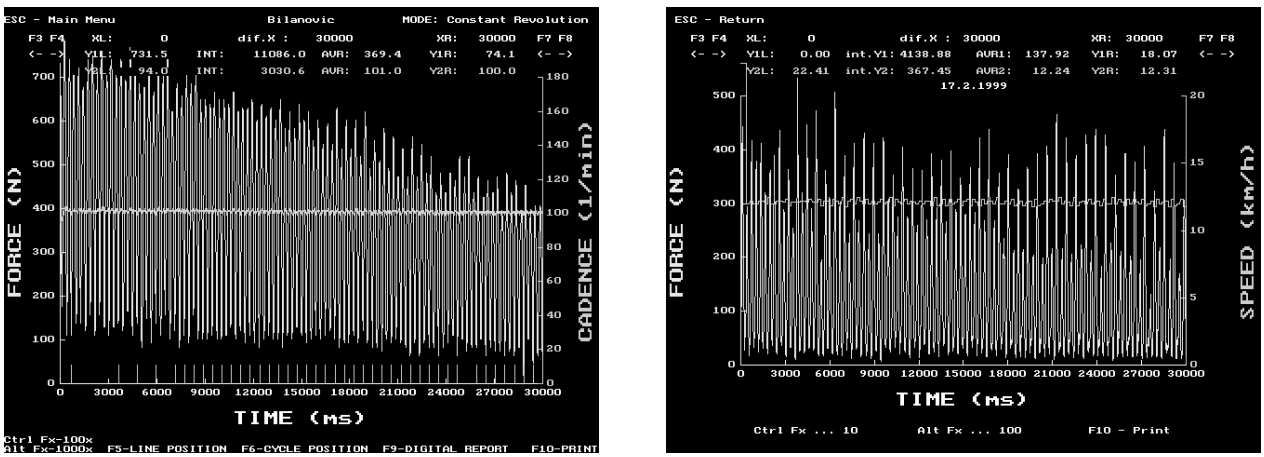
A group of 17 physical education students (mean age 21.8 ± 1.1 years, height 179.4 ± 5.9 cm, weight 75.3 ± 7.1 kg) volunteered to participate in the study. They underwent in random order on two different days a period of 30-second "all-out" cycling on the isokinetic ergometer at a revolution rate of 100 rpm and tethered running on the treadmill at a velocity of 13 km/h (Fig. 1). The loads employed were set at previously established maximal power produced in untrained subjects (Hamar et al., 1992; Hamar, Gažovič, & Schickhofer, 1994). The subjects started both exercises abruptly without any warm-up and stopped with a 2-minute period of 2 minutes of cooling-down.

During the load on the treadmill the subjects, in addition to running, had to pull a rope attached by means of a belt to the waist and anchored to the wall behind the device. A simple computer-based system consisting of a strain gauge, tensometer, tachodynamo, and AD convertor was employed to register the horizontal drag force, running velocity and to calculate the power (Fig. 2). From the raw data sampled at 100 Hz, 5-second interval values were calculated to plot the power/time charts. The following parameters were calculated: Pmax (initial 5-second period), Pmean (average value calculated from the entire 30-second test), and Fatigue index (the ratio of power decline Pmax-Pmin and Pmax).

In the previous study (Zemková & Hamar, 1999) the reliability of the manifested maximal running power during 30-seconds "all-out" tethered running at different velocities was verified. Test-retest correlation coefficients of maximal power ($r = 0.845$), mean power ($r = 0.916$), and fatigue index ($r = 0.879$) were similar as shown, e.g. by Montgomery, Douglass and Deuster (1989) or Nicklin and associates (1990). These values, and hence also the reliability of the running power measurement were better at the lower 8 km/h ($r = 0.926$) than at the higher 18 km/h velocities ($r = 0.848$). Analysis of the repeated measures revealed a measurement error from 5.4 to 8.7%, which is in the range comparable to common motor tests (Seger et al., 1988; Nicklin et al., 1990; Hamar, Gažovič, & Schickhofer, 1994) indicating that such a method may be applied in sport practice.

During exercise on the cycle ergometer as well as during the tethered running the parameters of heart rate were continuously monitored using the Heart Rate Monitor Polar Accurex Plus.

Figure 1. The isokinetic cycling and tethered running on the treadmill.



P = F x 2π x r x f
Cycling on the isokinetic ergometer

Drag power = F x v
Tethered running on the treadmill

Figure 2. An example of the results from the isokinetic cycling and tethered running on the treadmill (P – power, r – crank length, f – revolution rate, F – force, v – running velocity).

Blood samples from the fingertip were taken in the 6th minute of the recovery for the estimation of lactate concentration. The enzymatic method (Boehringer sets) was used for the analysis.

A paired *t*-test was employed to determine the statistical significance between the variables of isokinetic cycling and tethered running, $p < 0.05$ walues were considered significant.

Results

The correlation analysis showed (Fig. 3) a close relationship between the parameters of anaerobic capacity achieved in the 30-second "all-out" tethered running on the treadmill and cycling on the isokinetic ergometer, such as maximal power (r = 0.877), mean power (r = 0.920), and fatigue index (r = 0.896).

The tethered running and isokinetic cycling did not differ significantly either in maximal power (745.2 ± 143.7 W and 757.1 ± 130.7 W, respectively) or in mean power (598.4 ± 87.6 W and 614.9 ± 80.6 W, respectively). However, the fatigue index and blood lactate concentration were significantly ($p < 0.05$) higher in tethered running (30.8 ± 6.1% and 12.5 ± 1.3 mmol/l, respectively) than in cycling (26.9 ± 13.9% and 10.6 ± 1.4 mmol/l, respectively).

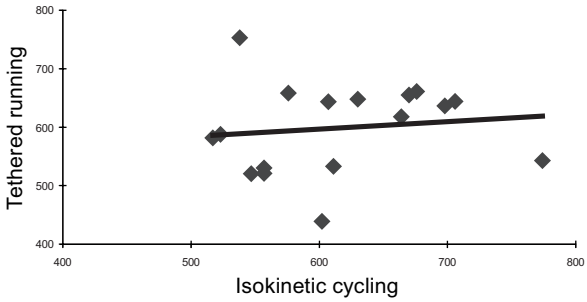


Figure 3. Relationship between the power produced during tethered running and isokinetic cycling.

Discussion and conclusions

Similar values of maximal and mean power during the exercise modes examined indicate that the 30-second "all-out" tethered running on the treadmill may represent an acceptable alternative for the assessment of anaerobic capacity. However, in comparison with isokinetic cycling slightly higher values of fatigue index and blood lactate can be achieved, in particular at higher velocities (Zemková, Hamar, & Schickhofer, 1999). This fact should be taken into consideration if such an exercise is employed.

Using this method the actual state as well as the specific training effect may be evaluated, as has been shown in the case of four-week karate training focused on the improvement of anaerobic capacity (Zemková, Hamar, & Schickhofer, 1999). In contrast, no changes in the power output have been found following the same period of karate training assessed by the 30-second "all-out" load on the isokinetic cycle ergometer.

These differences may be ascribed to the specific adaptation due to the preferred exercise mode used for anaerobic training. Therefore, in order to obtain the relevant information concerning anaerobic capacity, any exercise similar to the ones used during training should be preferred, such as jumping, cycling, stair uphill running, paddling, rowing, tethered swimming, tethered running, etc. Contrary to the untrained population, in which one of the standard tests can be applied, in athletes it should be the activities which involve the same or similar muscle group and movement patterns as during sport-specific tasks.

This may be corroborated by the results of our previous study (Hamar & Zemková, 2000) in which the analysis of power during short term bouts of cycling and tethered running showed that sprinters performed significantly better on the treadmill than on the cycle ergometer and cyclists achieved higher "all-out" power during cycling than during tethered running. Thus, in some sports tethered running on the treadmill may be considered as a more specific and hence more suitable alternative for the assessment of anaerobic capacity.

This finding is in agreement with the recent reports of several authors (Lakomy, 1985; Cheetham & Williams, 1985; Cheetham, Boobis, & Brooks, 1986; Nevill, Boobis, & Brooks, 1989; Lakomy, 1994; Falk, Weinstein, Dotan, Abramson, Mann-Segal, & Hoffman, 1996; Jaskólski, Veenstra, & Goosens, 1996; Jaskólska, Goosens, & Veenstra, 1999) who documented that such a method allows the evaluation of specific sprint-running anaerobic power.

Also, the deficiency of validity that has been demonstrated by the rather moderate correlation coefficients ($r = 0.69$ to 0.86) between the power outputs in various forms of anaerobic tests performed on the cycle ergometer to the spring-running performance for 50 yards to 300m (Bar-Or & Inbar, 1978; Tharp, Newhouse, Uffelman, Thorland, & Johnson, 1985; Patton & Duggan, 1987), questions the suitability of cycling exercise for the sport-specific assessment of anaerobic capacity.

Therefore, tethered running on the treadmill seems to be a suitable method providing useful information concerning the ability to exert maximal anaerobic power (highest 5-second period) and anaerobic endurance (mean 30--second power and fatigue index), namely, for weight-bearing athletes. However, further studies are needed to validate this method on large samples of specific sports as well as different age groups and populations.

Taking into account no significant differences in the maximal and mean power production between the exercise modes examined, it may be concluded that 30-second "all-out" tethered running on the treadmill represents an acceptable alternative for the assessment of anaerobic capabilities. However, in comparison with isokinetic cycling slightly higher values of fatigue index and blood lactate have to be expected.

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MAKSIMALNO TRČANJE NA POKRETNOM SAGU SA SVLADAVANJEM OTPORA KAO ALTERNATIVA ANAEROBNOM TESTU WINGATE

Sažetak

Uvod

Maksimalno opterećenje na bicikl-ergometru tipičan je oblik vježbanja koji se koristi za procjenu anaerobnoga kapaciteta u laboratorijskim uvjetima. Međutim, pedaliranje za mnoge sportove nije ekvivalentna mišićna aktivnost zato što ne omogućuje specifičan oblik mišićnog rada. Za većinu aktivnosti s opterećenjem, trčanje se čini prikladnijom alternativom. Međutim, u jednostavnom slobodnom trčanju na pokretnom sagu praktički nije moguće primijeniti maksimalno radno opterećenje u ograničenom vremenu. Taj se nedostatak može izbjeći primjenom modificirane aktivnosti koja se zove trčanje na pokretnom sagu sa svladavanjem otpora *(tethered running),* za vrijeme koje ispitanik, osim što trči, povlači za svoj pojas pričvršćen konopac koji je pričvršćen na zid iza saga za trčanje. U konopac je ugrađena dinamometrijska sonda. Jednostavan računalni sustav može se koristiti za praćenje sile povlačenja, brzine trčanja i za izračunavanje postignute snage trčanja. Prikupljeni podaci ukazuju na to da sila ovisna o frekvenciji koraka i snaga fluktuiraju u vremenu te omogućuju izračunavanje vršnih (maksimalnih) i prosječnih vrijednosti sile i snage za određeni period. Ponavljani kratkotrajni sprintovi (maksimalno brzo trčanje), u trajanju od 5 do 10 sekundi, sa svladavanjem otpora pri različitim brzinama pokretnog saga daju podatke koji se mogu koristiti za konstruiranje individualnih krivulja sile-brzine, odnosno snage-brzine. Slično kao i u ostalim vrstama mišićne aktivnosti, i ovdje se javlja pad ukupne sile s povećanjem brzine. Osim toga, ukupna snaga raste od nižih brzina, postiže maksimum te potom, s približavanjem višim brzinama, opada. Maksimalna snaga povlačenja i korespondirajuća brzina također se može izvesti iz takve krivulje. Tako maksimalno trčanje na pokretnom sagu, u trajanju od 30 sekundi, sa svladavanjem otpora, kao pandan testu Wingate, također daje podatke o maksimalnoj i prosječnoj snazi, na osnovi čega se može izračunati indeks umora. Međutim, suprotno u literaturi dobro dokumentiranim i često korištenim maksimalnim testovima na bicikl-ergometru, o testu trčanja sa svladavanjem otpora nedostaju dokumentirane informacije vezane uz parametre anaerobnih sposobnosti. Cilj je stoga ovog istraživanja bio usporediti parametre anaerobnih sposobnosti (maksimalna i prosječna snaga, indeks umora i laktati u krvi) dobivenih u maksimalnom testu od 30 sekundi izvedenom na izokinetičkom bicikl-ergometru s onim parametrima prikupljenima testom trčanja na pokretnom sagu sa svladavanjem otpora.

Metode

Grupa od 17 studenata tjelesnog odgoja (prosječna dob 21,8±1,1 godina, visine 179,4±5,9 cm, težine 75,3±7,1 kg) dobrovoljno je sudjelovala u istraživanju. Prema slučajnom rasporedu ispitanici su izvodili maksimalni test u trajanju od 30 sekundi na izokinetičkom bicikl-ergometru, uz brzinu okretaja od 100 okretaja/min, i test maksimalnog trčanja na pokretnom sagom sa svladavanjem otpora pri brzini saga od 13km/h u dva različita dana. Koristilo se opterećenje utemeljeno na ranije utvrđenoj vrijednosti maksimalne snage na uzorku netreniranih ispitanika. Ispitanici su počeli izvoditi oba zadatka naglo, bez zagrijavanja, a završavali su s dvije minute opuštanja i hlađenja. Za vrijeme opterećenja na pokretnom sagu ispitanici su uz trčanje morali povlačiti uže pričvršćeno za sredinu pojasa i za zid iza uređaja. Jednostavan računalni sustav koristio se za praćenje sile povlačenja, brzine trčanja i izračunavanje proizvedene snage. Iz sirovih podataka prikupljenih pri 100 Hz, izračunate su vrijednosti u intervalima od 5 sekundi kako bi se grafički prikazali odnosi postignute sile u vremenu.

Rezultati

Izračunati su sljedeći parametri: Pmax (inicijalni period od 5 sekundi), Pmean (prosječna vrijednost izračunata na osnovi cijelog trajanja testa, 30 sekundi) i indeks umora (omjer opadanja snage, razlike Pmax i Pmin i Pmax vrijednosti).

Rasprava i zaključak

Za vrijeme vježbanja na bicikl-ergometru, kao i za vrijeme maksimalnog trčanja sa svladavanjem otpora kontinuirano je praćena frekvencija srca. Uzorci krvi iz prsta uzimali su se u šestoj minuti oporavka kako bi se procijenila koncentracija laktata. Korelacijska analiza

pokazala je visoku povezanost između parametara anaerobnih sposobnosti dobivenih za vrijeme trčanja na sagu u trajanju 30 sekundi sa svladavanjem otpora i vožnje na izokinetičkom bicikl-ergometru, kao što su maksimalna snaga (r=0.877), prosječna snaga (r=0.920) i indeks umora (r=0.896). Trčanje sa svladavanjem otpora i izokinetičko bicikliranje ne razlikuju se statistički značajno ni po maksimalnoj snazi (745.2±143.7 W i 757.1±130.7 W) ni po prosječnoj snazi (598.4±87.6 W i 614.9±80.6 W). Međutim, indeks umora i koncentracija laktata u krvi statistički su značajno bili veći u maksimalnom trčanju sa svladavanjem otpora (30.8±6.1% i 12.5±1.3 mmol/l; $p<.05$).

Uzme li se u obzir da se nije pokazala statistički značajna razlika u ispoljenoj prosječnoj i maksimalnoj snazi između korištenih modaliteta vježbanja, može se zaključiti da je maksimalno trčanje na pokretnom sagu u trajanju od 30 sekundi sa svladavanjem otpora prihvatljiva alternativa za procjenu anaerobnog kapaciteta. Međutim, u usporedbi s izokinetičkim bicikliranjem, mogu se očekivati više vrijednosti indeksa umora i koncentracije laktata u krvi.