The body balance disturbation tolerance skills during increasing physical exertion as an important criterion for assessing personal safety

Authors' Contribution:
- **A** Study Design
- **B** Data Collection
- **C** Statistical Analysis
- **D** Manuscript Preparation
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Abstract

Background & Study Aim: Concern for personal safety fills the entire ontogeny of each individual human being. The phenomenon of the body balance disturbation tolerance skills (BBDTS) is important if only because we belong to the homo erectus species and an unintentional loss of vertical posture most often results in a fall or a collision with a vertical obstacle. The aim of our pilot study is to gain new knowledge about the capabilities of BBDTS by a professional hockey player during different phases of an intensive training session simulating a twenty-minute physical effort of the first period of a hockey game.

Material & Methods: Professional hockey player was studied: 22 years old; 175 cm; 73 kg; more than ten years of training experience. The reference system for the hockey player's performance is the performance of mountain bikers (n = 9) and horse riders (n = 7).

Has been applied Rotational Test' (RT – quasi-apparatus version) measured the BBDTS. RT consists of six tasks (consecutive jumps with body rotation of 360° alternately to the right and to the left). Evaluation criteria: landing after the jump with body rotation on the designated line with both feet and maintaining balance means the lack of the error (the result is recorded as "0"), no contact of one foot with the line after landing is assessed as "1" (first degree error), "2" means the lack of contact with the line after landing or not maintaining this contact while correcting the posture (second degree error), "3" records leaning against the ground with a hand/hands or a fall (third degree error). The overall result (motoric aspect) is the sum of the six tasks and includes 0 to 18 stipulated points. Criteria of an individual level of BBDTS are as follows: very high (0-1), high (2-3), average (4-9), low (10-12), very low (13-15), insufficient (16-18). Test execution time – the optimal result is obtained after ca. twelve seconds. It is a complementary information (documented with an accuracy up to 0.01 second).

Results: Professional hockey player best tolerated body imbalance after performing a training session (RT score = 1 point). Mountain bikers also tolerated body imbalances better after specific cycling training (M = 7.11 ±0.35 points). In contrast, the average performance values of horse riders were higher after 60 minutes of riding training (M = 10.43 ±3.41points). The comparative performance of the hockey player and the mountain biker leader testifies to the different profiles of the phenomenon under study in the motor sense. Profile of a hockey player from first trial (before warm-up) to third trial: 11-, 7-, 5-, 3-, 1 point; similarly of a cyclist: 4-, 3-, 6-, 3-, 5 points. RT time-based profiles are very similar.

Conclusions: Two phenomena are a clear finding of this pilot study. First, the specific effort involved in sporting activities modifies the BBDTS in the course of its accrual and is determined, among other things, by the individual level of training. Secondly, the quality of these modifications measured multidimensionally is related to the state of those components of the neurophysiological system that are responsible for maintaining stable posture during human motor activity. Future research should answer the question to what extent appropriate training can serve to maintain optimal BBDTS throughout an individual's ontogeny. It is an open question to what extent the current RT formula may be applicable to the study of individuals with lower limb conditions.

Keywords: BBDTS • effort safety • motor safety • nutritional security • survival

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Effort safety – is consciousness of the person who starts physical effort or consciousness of the subject who has the right to encourage or even enforce from this person the physical effort of a certain intensity and duration, who it is able to do so without risking life or health [55].

Motor safety – is consciousness of the person undertaking to solve a motor task or consciousness the subject who has the right to encourage and even enforce from this person that would perform the motor activity, who is able to do it without the risk of the loss of life, injuries or other adverse health effects [55].

INTRODUCTION

Concern for personal security fills the entire ontogeny of each individual. However, there is no unified view among researchers regarding a coherent personal safety (effort and motor see glossary, etc.) evaluation system, although intuitions are similar. That is to say, although various research results reliably inform about phenomena concerning especially human functioning in extreme situations, the recommendations to date do not formulate a relatively comprehensive solution. In methodological terms, this situation is not surprising, as the very concept of 'personal safety' encompasses each individual and the myriad circumstances in which a particular individual functions or may suddenly find himself or herself against his or her own will (immeasurable collapse, unexpected attack by an aggressor, communication breakdowns, etc.).

A simplified unification of this issue is RM Kalina's proposal of the profile of subjective sense of positive health and survival abilities (and then objectively measure the indicators used) as a diagnostic tool applicable in different circumstances [1] – i.e. it is a relatively consistent model for verifying a basic sense of personal security. In this profile, the D dimension (survival abilities) is based on eight indicators, either collective (average score of at least two specific indicators) or individual: body balance disturbation tolerance skills (BBDTS); precision skills before and during activity; safe falling skills; self-defence skills; swimming ability; lifesaving skills in water; first aid skills, survival abilities in solitude [1, 2].

The BBDTS phenomenon [3] is important if only because we belong to the *homo erectus* species and unintentional loss of vertical posture most often results in a fall, or a collision with a vertical obstacle. In the results of studies of the BBDTS phenomenon under changing conditions of physical (psychophysical) exertion load that have been made available to date, most publications concern simulated military operations – especially the combination of physical exertion and sleep deprivation [4-8]. The effect on this phenomenon of physical exertion performed alternately in sportswear and firefighter's combat gear is also well known [9].

In addition, the following, among others, were studied: airborne troops before and after completing eight months of military service [10]; female students before and after completing an eight-month training course based on gymnastics and dance exercises with elements of self-defence [11]; physiotherapy students before and after a two-semester safe fall course [12,]; physical education students with varying experience of many years of sports training (combat sports versus other sports) before and after completing a multi-day alpine skiing course – one recent study [14]. In some experiments, the result was related to control groups [15, 11, 12, 13, 14, 8]. These observations are characterised either by the common property of being affected by relatively homogeneous stimuli on the subjects in terms of their intensity, duration (from several days to several months) and content [4-7, 14], or by differences in content [11, 3, 12, 16] or all of the above-mentioned indicators [17, 8].

Correlations of BBDTS with both general and/or specific physical fitness test scores are known [15, 11, 9, 12]. There are few experimental results reporting the correlation of BBDTS with an elementary personal safety phenomenon – the susceptibility the body injuries during the fall [18-20]. The results of a correlation study of the two are expected using the new version of "the susceptibility test to the body injuries during the fall" (STBIDF-M) [21].

However, there is a lack of empirical data on the BBDTS of athletes performing either specific efforts related to their competitive activity or intensive physical efforts to stimulate a desired level of fitness. This issue is primarily related to the personal safety of athletes in training, and this is related to the prevention of body injuries in the broadest sense.

The aim of our pilot study is to gain new knowledge about the capabilities of BBDTS by a professional hockey player during different phases of an intensive training session simulating a twenty-minute physical effort of the first period of a hockey game.

MATERIAL AND METHODS

Participants

Hockey player, age 22, height 175 cm, weight 73 kg. More than 10 years of training experience, including 4 years of playing in the Polish Hockey League (highest sport class).

The system of reference for the hockey player's results is mountain bikers [22] and horse riders [23]. Mountain bikers: 9 riders (6 men, 3 women) from the Sport Club "Luboń" Skomielna Biała, Poland. Athletes aged 11 to 21 (mean 15.78), body height 152 to 184 cm (mean 172), body weight 37 to 65 kg (mean 54.56). Riders: 7 riders (6 women, 1 man) of the "Bór" Toporzysko Sports Club, Poland aged 16 to 19 (mean 17.2), body height 162 to 180 cm (mean 174.4), body weight 51 to 63 kg (mean 60 kg). Training experience of two riders seven years, three riders six years, two riders five years.

The study of the hockey player was carried out as part of the „health related training" subject (participating observation) in Podhale State College of Applied Sciences in Nowy Targ, Poland. In contrast, the research on mountain bikers and equestrians was carried out as part of a promotional thesis (bachelor level), with the approval of the local bioethics committee of the same College.

Study design

The subjects performed 'Rotational Test' (RT – quasi-apparatus version) measured the BBDTS [3]. RT consists of six tasks (consecutive jumps with body rotation of 360° alternately to the right and to the left). Evaluation criteria: landing after the jump with body rotation on the designated line with both feet and maintaining balance means the lack of the error (the result is recorded as "0"), no contact of one foot with the line after landing is assessed as "1" (first degree error), "2" means the lack of contact with the line after landing or not maintaining this contact while correcting the posture (second degree error), "3" records leaning against the ground with a hand/hands or a fall (third degree error) [3].

The overall result (motoric aspect) is the sum of the six tasks and includes 0 to 18 stipulated points. Criteria of an individual level of BBDTS are as follows: very high (0-1), high (2-3), average (4-9), low (10-12), very low (13-15), insufficient (16-18). Test execution time – the optimal result is obtained after ca. twelve seconds. It is a complementary information (documented with an accuracy up to 0.01 second) [3].

The movie is available at the website of the journal Archives of Budo (www.archbudo.com) in the left menu (section: ArchBudo Academy) under link 'Rotational Test' (http:// www.archbudo.com/ text.php?ids=351).

The common element of each empirical system was only the BBDTS measurement before the warm-up and after the active part of the training session. However, the hockey player and cyclists performed RT five times, while the riders performed RT twice.

The hockey player's empirical system

First, the athlete performed an RT before the warm-up, then after an individual intensive warm-up (5 minutes), and a further three measurements were taken at the tenth, fifteenth and twentieth minutes of this training session (this was a simplified simulation of the effort during the first hockey period of a match). Each five-minute trial consisted of an interval: 30 seconds Burpee test, followed by 30 seconds active interval etc. The intensity of the effort was monitored using a sports tester (Polar RCX5). in relation to the age of the hockey player at the time of the study was 193 beats per minute (according to the Tanaka et al. [24] classification). The hockey player's effort intensity zones were referred to Pollock's et al. [25] recommendations.

Empirical system of mountain bikers

First, BBDTS measurements were taken before the warm-up, then after the warm-up. A further three measurements were taken during the main part of the training session based on a specialised effort – three laps of the same 3 km route. RT was repeated after each lap of the route – a total of five BBDTS measurements were taken [22].

Empirical system of horse riders

First, the BBDTS was measured before the equestrian training session, then after a 60-minute training session, the content of which was horse manage [23].

Statistical analysis

The estimation of the results is based on the following indicators: mean (M); minimum (Min); Maximum (Max); standard deviation (SD or ±).

RESULTS

The hockey player reduced BBDTS errors expressed in points (from 11 before warm-up to 1 after last trial) as the exertion increased and reduced the time from 17.81 seconds to 13.21 s. The effort during the last five-minute trial was performed at supramaximal intensity (HR = 205), and the earlier (from the before warm-up measurement falls consecutively into the zones of the: very light, hard, hard, very hard (Table 1).

The mountain bikers, in terms of average score, made fewer mistakes before warm-up (M = 7.67 ±3.81points) than the hockey player, but more than him by as many as more than 6 points after last trial (M = 7.11 ±1.96 2points). They were, however, behind the hockey players in average RT time – respectively 17.97- and 14.47 seconds. Both indicators (points and time) in relation to the cyclists' performance, however, show that at a slightly higher level they tolerate imbalances after the last effort of their own training session (Table 2).

The average RT score of the horse riders (both expressed in points and time) before training indicates their slightly higher BBDTS level relative to the hockey player. After the active phase of the compared training, the result is the opposite. Furthermore, in riders, both indicators show a deterioration of their BBDTS under the influence of 60 minutes of specific training with the horse (Table 3).

Table 1. The ability of a hockey player to tolerate body imbalances during rapidly increasing physical exertion under laboratory conditions.

Empirical system	Body rotation of 360° during jumps [points]						Indicator complex		
	1R	2L	3R	4L	5R	6L	points	time (s)	HR
before warm-up	2	2	2	2	1	2	**11** (1-2)	17.81	66
after warm-up	1	2	1	1	1	1	**7** (1-2)	15.45	136
I trial	0	1	0	2	0	2	**5** (0-2)	14.67	167
II trial	0	1	0	1	0	1	**3** (0-1)	14.55	185
III trial	0	0	0	1	0	0	**1** (0-1)	13.21	205
M	0.60	1.20	0.60	1.40	0.40	1.20	**differences between: before warm-up and III trial**		
SD	0.89	0.84	0.89	0.55	0.55	0.84			
Min	0	0	0	1	0	0	**10**	**4.6**	**139**
Max	2	2	2	2	2	2			

R right, **L** left

Table 2. The ability to tolerate body imbalances of mountain bikers (n = 9) during increasing physical exertion.

Empirical system	Body rotation of 360° during jumps [points]						RT indicator complex	
	1R	2L	3R	4L	5R	6L	Points	Time (s)
before warm-up	1.56±0.88 (0-3)	1.00±0.87 (0-2)	1.56±1.01 (0-3)	1.22±1.2 (0-3)	1.22±0.97 (0-3)	1.11±0.6 (0-2)	**7.67** ±3.81 (4-14)	17.97 ±2.81 (14.62-22.4)
after warm-up	0.89±0.78 (0-2)	1.22±0.83 (0-3)	1.56±0.53 (1-2)	1.44±0.73 (0-2)	1.67±0.71 (0-2)	1.11±0.78 (0-2)	**7.89** ±2.32 (3-11)	15.62±1.84 (13.12-18.53)
I trial	1.11±0.78 (0-2)	1.00±0.71 (0-2)	1.56±0.53 (1-2)	1.67±0.5 (1-2)	1.11±0.78 (0-2)	1.56±0.53 (1-2)	**8** ±1.87 (5-10)	14.83 ±1.49 (12.91-17.7)
II trial	1.11±0.78 (0-2)	1.11±0.78 (0-2)	1.44±0.53 (1-2)	1.11±0.6 (0-2)	1.33±0.5 (1-2)	1.44±0.53 (1-2)	**7.56** ±2.92 (3-11)	14.42 ±1.08 (12.63-15.78)
III trial	0.89±0.92 (0-2)	1.33±0.71 (0-2)	1.33±0.5 (1-2)	1.22±0.44 (1-2)	1.33±0.71 (0-2)	1.00±0.5 (0-2)	**7.11** ±1.96 (4-10)	14.47 ±1.35 (12.93-17.66)
M	1.11	1.13	1.49	1.33	1.33	1.24	**differences between: before warm-up and III trial**	
SD	0.27	0.14	0.10	0.22	0.21	0.24		
Min	0.89	1.00	1.33	1.11	1.11	1.00		
Max	1.56	1.33	1.56	1.67	1.67	1.56	**0.56**	**3.50***
Max	1.56	1.33	1.56	1.67	1.67	1.56		

R right, **L** left, *p<0.05

Table 3. Ability to tolerate body imbalances of horse riders (n = 7) before and after 60 minutes of riding training.

Empirical system	Body rotation of 360° during jumps [points]						RT indicator complex	
	1R	2L	3R	4L	5R	6L	Points	Time (s)
before training	1.57±0.53 (1-2)	1.57±0.79 (1-3)	1.57±0.98 (0-3)	1.57±0.53 (1-2)	1.29±1.11 (0-3)	1.57±0.98 (0-3)	9.14±3.24 (5-13)	17.34 ±2.17 (14.65-20.11)
after training	1.86±0.9 (0-3)	1.57±0.98 (0-3)	1.71±0.49 (1-2)	1.71±0.95 (0-3)	1.71±0.76 (0-2)	1.86±0.69 (1-3)	10.43±3.41 (4-13)	19.16 ±1.93 (16.67-21.78)
M	1.71	1.57	1.64	1.64	1.50	1.71	**differences**	
SD	0.20	0.00	0.10	0.10	0.30	0.20		
Min	1.57	1.57	1.57	1.57	1.29	1.57	**1.29**	**1.82***
Max	1.86	1.57	1.71	1.71	1.71	1.86		

R right, **L** left, *p<0.05

The individual profiles of the hockey player and the mountain biker leader provide evidence of different BBDTS adaptation patterns under circumstances of increasing physical exertion load identified by errors made during jumps with body rotation of 360° (Figure 1). Although the cyclist landed more often without errors (46.46% out of the 30 pivot jumps performed (hockey player 33.33%) and made fewer second-degree errors (score: 26.66%) – both made 36.66% first-degree errors each – respectively, the hockey player proved very high BBDTS and the cyclist average in the phase of the highest physical component exercise load average. The mountain biker leader was slightly faster than the hockey player in performing RTs during the four consecutive empirical system elements, but the hockey player was faster by 1.8 seconds during the last RT ending the training sessions (Figure 2).

DISCUSSION

Indicator complex provide evidence that a high-performance hockey player, in each of the measured aspects of effort (motor, physical, physiological)

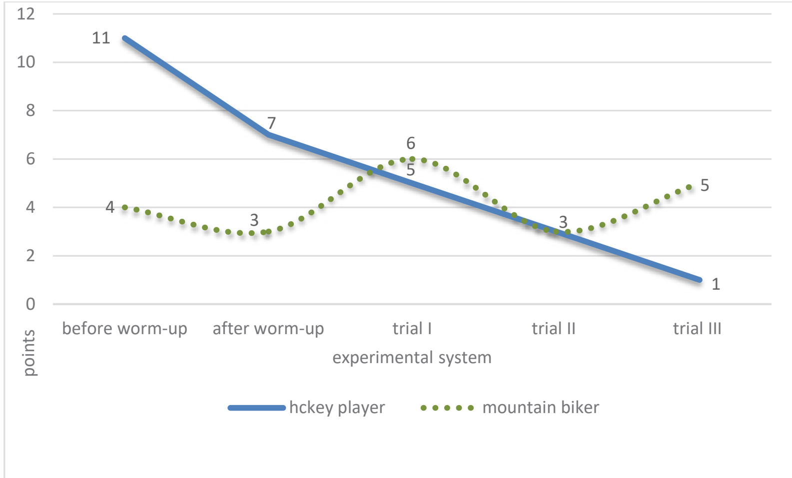

Figure 1. Profiles of the ability to tolerate body imbalances by a hockey player and a mountain biker leader based on motor indicators (RT points reporting errors).

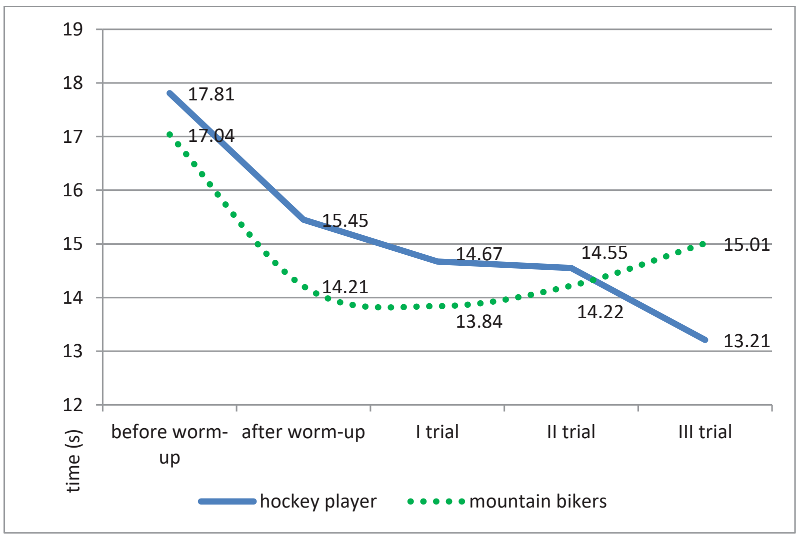

Figure 2. Profiles of the ability to tolerate body imbalances by a hockey player and a mountain biker leader based on the timing of individual RTs (in seconds).

during the simulated first period of a match, increasingly tolerates the body imbalances caused by an experimental, motor-identical [3], physical effort of an athlete. This repeated experimental element (i.e. RT) was integrated into the simulated psychophysical effort of the first period of a hockey match (20 minutes of 'pure, intermittent effort' slightly extended due to the measurements taken). HR informed the physiological response of the body to exercise load with a very important mental component – the required focus of attention on the accurate execution of six dynamic motor tasks (body rotation of 360° during jumps), repeated at five-minute intervals. Thus, the number of errors made and their qualitative component (total points), as well as the execution time of each RT, only to a simplified degree and extent inform about the mental (psychological) involvement of the hockey player during this specific activity.

Such accurate information is not provided by the results of studies of mountain bikers [22] and riders [23]. In addition, only the experimental system of mountain bikers is similar to the experimental effort of the hockey player – five times RT: before-, after warm-up and during three trials. The important element that differentiates the efforts of the compared athletes (abstracting from time and intensity) is that for the hockey player it was a motor simulation of his starting activity, whereas for the compared athletes it was their specific efforts, relevant to their starting activity during competitions. As the cognitive aim of this work is new knowledge about the BBDTS phenomenon in different circumstances of human physical activity, so the recorded data are sufficient for the comparative study undertaken. The hockey player's performance is just an exemplification of the creation of repeatable experimental systems, that will provide the expected knowledge derived from observations controlled under very similar conditions (stable temperature, humidity, lighting, absence of unexpected confounding factors, etc.). Repeated training in field conditions does not guarantee such standards.

By just respecting the measurement standards based on the similarity criteria of the test conditions, it is already known that, among the various, multi-year, specific psychophysical activities, BBDTS are the most effectively stimulating (average RT score in brackets): performing on horseback (0.33), gymnastics (0.43), sport dance (0.44), basketball (1.11), judo (2) [3]. The model of field research conducted, among others, by Tomczak [4-8] is based on different criteria – RT performed at the place where the effort is currently continued. A mixed variant of field research consists of repeating RT in the same place, with changing external conditions (different obstacles, different route, different weather conditions, etc.) – these criteria were followed, among others, by studies of mountain bikers [22] and riders [23], as well as projects by other researchers [10, 11, 9].

Thus, from the perspective of enhancing personal safety, relativized to BBDTS, an important issue in a cognitive and applied sense is the further study of this phenomenon in various types of sporting, recreational, occupational activities – but especially those related to the performance of this work under conditions of extreme physical exertion and high emotional strain (soldiers, police officers, firefighters, rescuers, miners, high-altitude construction workers, etc.).

It is clear that the BBDTS phenomenon does not exhaust the issue of personal safety. However, this element is combined with the need to educate people about safe fall and avoiding collision. If a person loses a stable vertical posture, he either falls or collides with a vertical obstacle. If he or she is unable to avoid the collision, the mildest possible outcome may just be a loss of balance and a fall with no consequential injury.

Unique laboratory studies provide evidence that a trained man over sixty years old can protect his own body more effectively in circumstances of falling and colliding with hard ground [26], colliding with a concrete wall [27], or avoiding colliding with an object in motion [28], than a man 41 years younger, with experience of practising martial arts, among other things. However, there is still a lack of sufficiently generalized knowledge about enhancing personal safety by competently incorporating into various human physical activities not directly related to martial arts precisely the health exercises qualified to be a certain part of martial arts – examples are: taijiquan exercises recommended for the practice of basketball [29]; Chinese traditional exercise on cognitive function improvement in the elderly [30-33].

There is also a lack of knowledge about the effects of competent training to stimulate adequate levels of muscular strength using simple methods and measures [e.g. 34, 35], but with an emphasis on the importance of these forms of physical activity for personal safety. Related to issues directly related to human motor activity is the problem of optimal nutrition in a general sense (and with destructive factors), taking into account the specificity of extreme competitions [36-40], including professional sport [41, 42].

The unifying factor of this knowledge is the work dedicated both to survival in a broad sense [43, 1, 2, 44-46] and to the education of personal trainers. In the latter case, it is optimistic to report that there is a strong belief among this group of experts in the need to continuously expand general (100% of declarations) and also 100% of declarations regarding specialised knowledge [47]. A study from 10 years ago contradicts this trend – as much as 48% of the promotional work in physical education at one Polish university was not dedicated to this speciality, although at a comparable private university the result was more optimistic (14%) [48].

Moreover, this diversity of aspects of personal security is complemented by the specific phenomenon of 'emotional safety (security)' articulated *explicite* [49-51] or *implicite* [52, 53]. The various elements of personal security mentioned in this discussion demonstrate the complementary nature of the issue and are in line with the concept of innovative agonology, a new applied science whose primary method of research and education is precisely the complementary approach. In the cognitive sense, the prospect of associating RT results with apparatus measurements of body posture stability and recommended somatic indices may be interesting (see e.g. 54).

CONCLUSIONS

Two phenomena are a clear finding of this pilot study. First, the specific effort involved in sporting activities modifies BBDTS in the course of its accrual and is determined, among other things, by the individual level of training. Secondly, the quality of these modifications, measured multidimensionally (in the motor sense, the indicators are the number of tasks performed without errors, the points indicating the magnitude of the errors made during each of the six tasks, or lack thereof, and the sum of these points; while in the physical sense, it is the time of RT performance) is related to the state of those components of the neurophysiological system that are responsible for maintaining a stable posture during human motor activity. Future research should answer the question to what extent appropriate training can serve to maintain optimal BBDTS throughout an individual's ontogeny. It is an open question to what extent the current RT formula may be applicable to the study of individuals with lower limb conditions.

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