CASE REPORT

UDC: 61:79]:[616.748-08:615.825
DOI: 10.2298/VSP140228040P

The effect of whole-body vibration and resistance training on muscle strength in a 13-year-old boy with *m. biceps femoris* lesion and posttraumatic calcification

Efekti primene vibracionog treninga i treninga sa dodatnim spoljašnjim opterećenjem na razvoj snage kod 13-godišnjeg dečaka nakon lezije *m. biceps femoris* i posttraumatske kalcifikacije

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Abstract

Introduction. Skeletal muscle atrophy is a common adaptation after major muscle lesion of *m. biceps femoris* that results in numerous health-sport related complications. Resistance strength training and whole-body vibration (WBV) have been recognized as an effective tool, which attenuates atrophy and evokes hypertrophy. **Case report.** We presented a 13-year-old boy with a lesion of *m. biceps femoris* and post-traumatic calcification sustained in soccer training session 6 month prior participation in this study. The patient underwent training 3 times a week for 7 weeks, including unilateral progressive WBV + resistance training (RT) of the right hamstrings muscle group using WBV and weights. Hamstrings muscle strength was measured using a Cybex isokinetic dynamometer. At the end of week 4, the patient peak torque value of the involved leg increased from 39% body weight (BW) to 72% BW and bilateral deficit decreased from -64% to -35%; at the end of week 7 the participant's peak torque value of the involved leg increased from 72% BW to 98% BW and bilateral deficit decreased from -35% to -3%, respectively. **Conclusion.** Unilateral WBV + RT protocol evokes strength increase in the hamstrings muscle group. This case study suggests that adding WBV, as well as the RT program have to be considered in the total management of strength disbalance. Further studies are needed to verify the efficiency of WBV + RT protocol over the classic physical therapy exercise program.

Key words:
athletic injuries; young adult; muscular atrophy; femur; physical therapy modalities.

Apstrakt

Uvod. Atrofija skeletnih mišića česta je promena nakon lezije mišića *m. biceps femoris* koja rezultira brojnim zdravstvenim problemima nastalim u sportu. Trening snage sa dodatnim spoljašnjim opterećenjem (RT) i vibracioni trening (WBV) su dokazane metode smanjenja mišićne atrofije i povećanja hipertrofije mišića. **Prikaz bolesnika.** Prikazali smo dečaka, uzrasta 13 godina, sa lezijom *m. biceps femoris* i post-traumatskom kalcifikacijom koja je nastala na fudbalskom treningu šest meseci pre početka lečenja. Primenili smo unilateralno progresivno rastuće WBV i RT opterećenje mišića zadnje lože natkolenice desne noge. Trening je sprovođen u vremenskom periodu od sedam nedelja, tri puta nedeljno. Snaga mišića zadnje lože natkolenice merena je izokonetičkim dinamometrom (Cybex). Na kraju četvrte nedelje relativna vrednost momenta sile u odnosu na telesnu težinu (BW) desne noge povećala se sa 39% BW na 72% BW, dok se bilateralni deficit smanjio sa -64% na -35% u odnosu na početno merenje. Na kraju sedme nedelje lečenja, relativna vrednost momenta sile prikazanog dečaka u odnosu na BW desne noge povećala se sa 72% BW na 98% BW, dok se bilateralni deficit smanjio sa -35% na -3%. **Zaključak.** Unilateralni WBV i RT povećali su snagu mišića zadnje lože natkolenice. Ovo istraživanje ukazuje na mogućnosti uključivanja WBV i RT u protokole prilikom lečenja mišićnog disbalansa. Postoji opravdana potreba za daljim istraživanjima koja bi potvrdila veću efikasnost WBV + RT protokola nad klasičnim pristupom fizikalne terapije.

Ključne reči:
povrede, atletske; mlade osobe; mišići, atrofija; femur; lečenje vežbanjem.

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Introduction

Hamstring strain injuries mostly occur in activities that include elements of running or sprinting. In his study about hamstrings injuries Agre [1] suggests several causes that lead to injury of the hamstring musculotendinous unit. For example, the lack of flexibility, imbalances in hamstrings muscle strength ratio, poor running biomechanics, dyssynergic muscle contraction during running, improper warm-up activities and premature return to activities after uncompleted rehabilitation program are the factors that initiate such condition. According to Kujala et al. [2] in the lengthening phase of contraction, muscle is not always capable to adequately respond to stimuli, which results mainly in partial hamstrings muscle tear, but the authors also leave the possibility of other injury mechanisms. Muscle impairment prevalence due to quick extension of the lower leg at the knee joint is common occurrence. The reason could be found in motion which provokes elongation of hamstrings muscle fibers in order to decelerate the forward movement of the shin bone in the late swing phase. A paper by Petersen and Holmich [3] suggests that the moment of instantaneous change of muscle action from eccentric to concentric caries the highest incidence for injury. However, Croisier et al. [4] arise the question whether strength imbalances are the result of previous muscle injury, or inducement element for reinjury occurrence, or both.

Structural changes of myofascial tissue after injury consequently lead to a decrease in hamstring muscle strength [5]. Positive effects of resistance training (RT) on physical condition of both children and adolescents are achievable with suitably prescribed and supervised exercise programs [6]. Fyfe et al. [7] explain that positive effects of eccentric training and underlying physiological mechanisms were clarified over the last seven decades. Eccentric training took its necessary place in strength training. The authors also state the existence of a pile of evidence in the literature, in recent years, supporting benefits of eccentric exercise in treatment of number of tendinopathies, muscle strains, and in the anterior cruciate ligament (ACL) rehabilitation protocols. However, in recent years, whole-body vibration (WBV) draw a lot of attention of scientists and practitioners, and it was used as an additional tool in exercise prescription in order to improve neuromuscular properties in sport performance and rehabilitation, as well [8]. Also WBV has been proposed as the exercise method for injury prevention and rehabilitation [9–11].

RT and WBV have been suggested as effective interventions to address the loss of hamstring muscle strength following injury but the combination of both has not been reported in the literature. We studied the effect of combining RT and WBV on changes in hamstring muscle strength for the presented patient with a lesion of *m. biceps femoris*.

Case report

In this case report we investigated the effects of combining RT and WBV in a 13-year-old boy with a lesion of *m. biceps femoris* and post-traumatic calcification sustained in soccer training session 6 month prior to participation. The patient underwent training 3 times a week for 7 weeks, including unilateral progressive WBV and RT of the right hamstrings muscle group using WBV and weights.

Whole body vibration was provided by power plate next generation vibration platform (Power Plate North America, Chicago, IL), strength training was provided by a Space gym multigym unit (Space gym, Novi Sad, Serbia).

The intervention protocol for this study was intended to be progressive in RT as well as in WBV in regard to WBV frequency, amplitude, and duration, since this has previously been shown to be effective in healthy population [12]. The protocol consisted of supersets of RT exercise without vibration combining with WBV of the same biomechanical pattern.

Eccentric hamstring curl is performed using a leg-curl machine. A subject in lying position lifts weight with two legs and lowers the weight with the involved leg. The pelvic bridge is performed using a power plate. A subject lies with the knees bent 90° with the foots on a vibration platform. His/her performs a full double leg bridge hold in the top position and extend non-involved knee to full extension, then his/her as flexed in hips doing hip thrusts.

The Nordic hamstring exercise (NHE) is a bodyweight exercise. In the presented patient we used the NHE protocol described by Mjolsnes et al. [13]. The patient's starting position was kneeling from, then the patient lowered his upper body towards the ground by using eccentric contraction of the hamstrings muscle group, while the ankles were held down by a partner. We assumed that the NHE increase eccentric hamstring torque.

Due to insufficient muscle strength single legged squat was executed with the patient standing with one arm extended out in front and with the other one holding a vibration machine. The balance of the involved leg with the opposite leg extended straight leg forward as high as possible. The subject squats down as far as possible, while keeping leg elevated off the floor, keeping back straight and supporting knee pointed the same direction as foot supporting. Raising body back up to the start position until knee and hip of the supporting leg are straight. Progression for squatting while holding vibration machine with hand was 6, 8, 10, 12, 15 repetitions. When the patient was able to perform 15 repetitions holding a vibration machine with the hand he started to perform single legged squat, standing with both arms extended out in front and without holding thevibration machine. Single legged isometric stance was performed standing on a platform with flexion in knees of the involved leg of 110 degrees with the opposite leg extended straight leg forward as high as possible according to the modified protocol of de Ruiter et al. [14] (Table 1).

The patient underwent the WBV training protocol following progression parameters shown in Table 1.

Isokinetic measurement of concentric/concentric hamstring/quadriceps torque was measured using an isokinetic (Cybex – NORM – CSMI, Stoughton, Massachusetts) dynamometer. Testing had four sets. For the first two tests angular velocity was set at 60°/s with five repetitions of trial test, before four repetition tests. For the third and fourth sets, angular velocity was set at 180°/s with 4 repetitions and 15 repetitions, respectively. Test was performed for each leg. These sets were performed with a 2 min rest between the sets. The patients was

Table 1

Whole-body vibration (WBV) training protocol and WBV progresion parameters

Parameters	Exercise	Tempo	Repetitions (n)	Sets (n)	Rest (s)		
1st superset							
A1	Eccentric hamstring curl	61×	6	3	30		
A2	WBV pelvic bridge	31×	6	3	30		
2nd superset							
A1	Nordic hamstring exercise	61×		3	30		
A2	WBV isometric pelvic bridge			3	30		
3rd superset							
A1	Single legged squat	31×	6	3	30		
A2	WBV single legged isometric stance			3	30		
WBV progresion parameters							
Frequency (HZ/a)	Week 1 30Hz/2mm	Week 2 35Hz/2mm	Week 3 30Hz/4mm	Week 4 35Hz/2mm	Week 5 35Hz/2mm	Week 6 35Hz/2mm	Week 7 35Hz/2mm

n – number; s – seconds; × – movement is performed explosively with full acceleration; a – amplitude.

seating on the Cybex with his hip joint at approximately 90° flexion, the upper body secured with dual crossover straps and the waist secured by a waist strap. The range of motion of the knee was set at 90° of full extension, with the upper leg secured using the thigh strap to limit excess movement of the knee and the limb. The main variables tested were peak torque, total work, endurance ratio and average power. Before the commencement of each testing speed, the patient was allowed to familiarize himself with 3 trials. The non-involved limb was tested first. Verbal encouragement at a conversational level was given during testing. The testing apparatus was regularly calibrated according to the manufacturer instructions.

The peak torque deficit for both legs of extensor muscles strength was in the acceptable range ≤ 10% [15], but bilateral deficit of peak torque of flexors muscles showed the deficit of -64% for the speed 60/60 and -47% for the speed 180/180, respectively.

We noticed a decrease in flexors muscles deficit for the speed 60/60, -35%; 180/180, -8%, respectively two months later.

The third measurement showed the increase in the right leg flexors peak torque although it was a noticeable decrease in the left leg peak torque (Table 2).

Discussion

This protocol was conducted to determine the effect of combined WBV+RT on changes in the knee muscles strength in those with the lesion of *m. biceps famoris*. The in-

Table 2

Isokinetic values for the first, second and third measurements

Measurement	Extensors (Con)		Deficit	Flexors (Con)		Deficit
	Value	%BW	%	Value	%BW	%
First measurement						
Peak Torque (Nm - average)						
speed 60/60 Right	89	200	-10%	18	39	-64
speed 60/60 Left	99	220		49	107	
speed 180/180 Right	66	146	-8	26	57	-47
speed 180/180 Left	72	161		49	107	
Second measurement						
Peak Torque (Nm - average)						
speed 60/60 Right	98	218	-8	33	72	-35
speed 60/60 Left	89	200		50	110	
speed 180/180 Right	68	152	-4	33	72	-8
speed 180/180 Left	71	158		35	77	
Third measurement						
Peak Torque (Nm - average)						
speed 60/60 Right	103	229	-11	45	89	-3
speed 60/60 Left	92	206		46	92	
speed 180/180 Right	71	158	-5	41	89	-3
speed 180/180 Left	75	168		45	92	

BW – body weight.

tervention produced positive changes in the peak torque and the percentage of body weight values in the involved leg during tree testing phases both flexor and extensor muscles. Positive changes were noticed in the non-involved leg also but in fewer amounts. During the third testing we noticed a decrease in healthy leg flexor muscle peak torque, which could be attributed to internal factors of a subject's motivation.

To our knowledge, this is the first Serbian study of combined WBV and RT treatment in a 13-year-old boy with *m. biceps femoris* lesion and post-traumatic calcification. There are relatively few studies that investigate effects of combined WBV and RT in children. Relatively heterogeneous findings in studies could be attributed to different training protocols, WBV machines (vertical *vs* pivotal tilting platform), subject's condition, etc, which make it hard to compare the outcomes. For instance, Stark et al. [16] conducted WBV, physiotherapy, resistance training and treadmill training in bilateral spastic cerebral palsy children. The results of that study showed that after 6 months of training the combined method resulted in the increased maximal force in extension totally 7.9%. Mahieu et al. [17] observed isokinetic knee muscle strength of healthy young skiers aged 9–15 after a 6-week training period. The authors noticed changes in hamstring peak torque (pre 66.36 Nm, post 74.25 Nm, 11.88% increase at angular velocity of 60°/s; pre 56.46 Nm post 64.17 Nm 13.65% at angular velocity of 180°/s). Comparing our findings and the results from a study of Mahieu et al. [17] greater strength increase could be noticed in our study in hamstring peak torque after the treatment. The reasons could be found in the fact that Mahieu et al. did not superset WBV exercise with RT. Also the subjects from the study of Mahieu et al. were young athletes already in training so the amount of strength increase was expectedly lower, than with a subject with *m. biceps femoris* lesion. Supersets combined of WBV and RT make a distinction between this study and other investigations.

In a study by Clark et al. [18] the minor changes in hamstring peak torque (dominant leg pre 98.61 Nm, post 99.00 Nm; nondominant leg pre 97.30 Nm, post 103.64 Nm) was noticed after 4 weeks of Nordic eccentric training in healthy amateur football players, but the authors noticed the improvement in vertical jump which they attributed to the changes in the position of peak hamstring torque. Rauch [19] describes advantageous effects of WBV on the gain of muscle functions over regular activities. In a recent study of Moawd et al. [20] healthy adults performed RT after WBV sets of similar biomechanical pattern (half squat) followed by polymetric jump type exercises, placebo group performed WBV sets on a platform without vibrations. The authors noticed a superior, 8% increase in isometric strength knee flexion in the WBV group compared to the placebo. In a study by Karatrantou et al. [21] the authors show 11.77% increase in isokinetic hamstring strength after < 2 months WBV training in healthy adult females. Comparing our results with the results of Karatrantou et al. [21] a greater strength increase in this study is evident, which can be attributed to the different methodological approach. In orthopedic rehabilitation the improvement in knee stability and proprioception *via* increased effectiveness in muscle reflex excitability has been found [22]. In addition to rehabilitation purpose Semler et al. [23] found improved mobility in motor impaired children after WBV treatment.

One of possible mechanisms of strength increase due to combining WBV+RT could be found in a study of Davis et al. [24] where the authors explain that greater forces in muscle are generated by placement of a participant on a vibrating platform. In their study, Bressel et al. [25] notice that children have greater vibration transmissibility than adults in the ankle and hip area. Mechanical vibrations evoke reflex muscle contractions which are according to Cardinale and Bosco [26] "mediated not only by monosynaptic but also by polysynaptic pathways". In a recent study by Pollock et al. [27] recorded recruitment thresholds from 38 motor units (MU) before and after WBV. The authors noticed that lowest MU increased their threshold while in higher MU firing threshold was decreased. This information indicates that WBV has preferential effect on higher MU, which is responsible for strength and power output. The authors also indicate that such response on higher threshold MU exists due to the use of polysynaptic pathways, which are not related with low-threshold MU.

While it is not appropriate to generalize to all persons with a lesion of *m. biceps femoris* muscle and post traumatic calcification, based on the results of this case, the results support earlier literature with regard to improvement in strength ratio by resistance training alone [28] and WBV alone [29]. The results from the first measurement supported the literature findings regarding decreased hamstring muscle strength following injury [30, 31]. It seems that combining RT and WBV copies the effects of both training methods. The results of this case report might suggest the direction for future studies. The single greatest limitation of this investigation is that it is a case study and should not be generalized to other individuals with *m. biceps femoris* lesion and post-traumatic calcification. Progressive resistance training applied combined with WBV is similar or in a way modified to the protocols used by others [13, 31].

Lastly, the schedule of intervention was established to meet the demands of the patient (primary school pupil), which had a flue 10 days from the week 4 until the week 5 across the study. These factors, related to the individual participant, might have affected the outcomes of this case report.

Conclusion

The unilateral whole-body vibration + resistence training protocol provided strength increase in the hamstrings muscle group. The findings of this case report suggest that adding whole-body vibration, as well as the resistance training program, must be considered in the total management of muscle strength imbalance. More studies are needed to verify the efficiency of whole-body vibration + resistence training program over the classic physical therapy exercise program. Furthermore, on the basis of the evidence in this study it is possible to conduct one randomized controlled trial which will determine differences among the groups exercising only resistence training, only whole body vibration and resistence training + whole-body vibration. Further studies should investigate what is optimal dose response of intervention, i.e. intensity, duration, and frequency of whole body vibration. The dosage of resistence training regarding sets, repetitions, and resistance is widely understood but in a combination with whole-body vibration is still unclear.

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Received on February 28, 2014.
Revised on May 14, 2014.
Accepted on June 26, 2014.
Online First June, 2015.