GROUND REACTION FORCES IN PERFORMANCE OF STEPS IN STEP AEROBICS AT VARYING HEIGHTS OF STEP BENCH

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Abstract:

Kinetic parameters of ground reaction force were analysed during step exercises of stepping on and off a step bench in order to determine the predictive biomechanical performance indicators for fundamental steps in step aerobics (*basic step, step touch*) at varying heights of the step bench. Nine subjects, professional step aerobics instructors, agreed to participate in this study (four males, five females). On the basis of the ground reaction force, the basic statistical parameters of the following components were calculated: ***Fx*** (*mediolateral*), ***Fy*** (*anteroposterior*) and ***Fz*** (*vertical*). The data were subsequently processed using non-parametric statistics for the dependent samples. More specifically, the Wilcoxon matched pairs test was used in order to calculate the differences in performances of identical steps at varying bench heights and in performances of various steps at identical bench heights. Statistically significant differences in ***Fx***, ***Fy*** and ***Fz*** were obtained depending on two factors. The first factor consisted of the specifics of the technique used for the complete (*basic step*) or partial (*step touch*) transfer of body weight from one leg to the other. The second factor was the overall amplitude of body movement as each single step was being performed at varying heights and following increases in bench height (15, 20 and 25 cm), which thereby increased the overall intensity of performance.

Key words: *step aerobics, ground reaction force (GRF), aerobics instructors, Wilcoxon non-parametric matched pairs test, step touch, basic step*

Introduction

A typical step aerobics workout consists of stepping on and off a step bench, requiring the participants to perform simple and complex movement structures in the aerobic work load physiological zones.

Aerobics instructors are a particularly interesting group of subjects because aerobics is one of a few kinesiological activities in which instructors are often more physically active than the trainees they instruct (Sekulić, 2001). During step aerobics classes, instructors perform movements that are somewhat exaggerated so that their group, facing them and following their performance, can clearly understand how the movements should be executed. Moreover, instructors must ensure that students perceive and acquire every phase of the movement, as mastery of each phase is crucial for the technically correct execution of the entire movement. This modality of work imposes particularly high stress levels upon the instructors' locomotor as well as cardio-respiratory system, the latter especially if we bear in mind the fact that instructors speak, i.e give additional instructions verbally simultaneously with demonstrating the movements.

Ground reaction force is a three-component vector that reflects complex body dynamics as a whole during the execution of the studied movement structure. In the ground reaction force signal, and because of the wave shape morphology and its relationship to technique, certain movement structures may yield information regarding the specific way in which these structures are executed, in turn reflecting the individuality of certain subjects (Medved, 1988). In some cases, however, it is possible to differentiate and track any progress in technique performance quality. Based on the data thus obtained, attempts can then be made to adjust the training process to accomplish the desired goals (Medved & Tonković, 1991).

Step aerobics belongs to a group of classical aerobics programmes and to those polystructural conventional activities in which movement structures are performed in a succession and repeated (Metikoš et al., 1997). The majority of movement structures in step aerobics programmes are of a low intensity, which significantly reduces the risk of locomotor system injuries (Sekulić, 2001; Juriša, 2001).

Since the 1950'es walking and running, the most natural examples of human locomotion, have been the subject of a paramount research area focusing on ground reaction force measurements (Saunders, Inman, & Ebehart, 1953; Herzog, Nigg, Read, & Olsson, 1989; Kadaba et al., 1989; Winter, 1990; Wimmer & Andriacchi, 1997; Medved & Kasović-Vidas, 1999; Čoh, Milanović, & Dolenc, 2000; Nigg, 2000; McNitt-Gray, Hester, Mathiyakom, & Munkasy, 2001; Medved, 2001) as a component of integrated research regarding healthy and pathological walking. The determination of biomechanical indicators during step analyses in aerobics, especially in step aerobics, was relevant to the following studies: Michaud, Rodriguez, Zayas, Armstrong, and Hartnig (1993) analysed the vertical component of ground reaction force during the execution of different movement structures of high-impact (HI) and low-impact (LO) aerobics workouts. No significant differences were obtained between the two modalities of work. In low-impact step movements, the ground reaction force equals the force exerted during normal everyday walking (Sekulić, 2001). Machado and Abrantes (1998) confirmed in their research that increases in step intensity resulted in corresponding increases in total activity impact. Indeed, increases in bench height (Santos-Rocha, Veloso, Franco, & Correia, 2001) and music tempo (Santos, Franco, Correira, Veloso, 2000) appear to increase ground reaction force (Farrington and Dyson, 1995; Bezner et al., 1996; Maybury & Waterfield, 1997; Terriet & Finch, 1997), and this observation should perhaps be considered during the selection of physical exercise programmes. The height of a step bench reduces the time interval between the initial contact and the moment of achieving the maximum ground reaction force, which in turn leads to increases in mechanical work load and can therefore influence the way in which the type and technique of movement are adapted (Santos-Rocha et al., 2001).

By studying the mechanical loads and overloads of the lower extremities, Santos-Rocha and Veloso (2004) analysed the ground reaction force exerted by the joints of the lower extremities (ankle, knee and hip joints) and the momentum achieved during various steps in step aerobics. The objective of their study was to improve technique, prevent muscle and skeletal injuries, and design proper rehabilitation and exercise programmes. Equal ground reaction force and reaction force values were obtained on the ankle joint, whereas the reaction force values observed on the other two joints were lower. Santos-Rocha and collaborators (2004, 2006) collected the kinematic parameters of the ankle, knee and hip joints, as well as the ground reaction force exerted during the execution of the characteristic steps following variations in music tempo. The aim of this study was to develop a model for the lower extremities and to obtain internal and external load values during step aerobics in accordance with the choreography technique and the number of steps in order to improve or maintain health and achieve optimal levels of preparedness and/or rehabilitation. Santos-Rocha, Oliveira, & Veloso (2006) studied step aerobics programmes in order to confirm the observation that step aerobics may improve and maintain the optimal status of the skeletal system based on the osteogenic index (OI) (Turner & Robling, 2005), ground reaction force (GRF) with the tempo of step execution determined by the music tempo of 134.6±4.7 beats per minute (bpm). Increases in tempo (above 135 bpm) were accompanied by significant increases in osteogenic index and ground reaction force values. Hence, such fast tempos should perhaps be used only in high-impact step aerobics classes. Using the sample of experienced step aerobics instructors, Machado, Santos-Rocha, and Veloso (2006) analysed differences resulting from variations in speed during the execution of different steps and they analysed the ground reaction force with regard to the following: the first vertical peak (FZ) and vertical load (LRZ) normalized with the subjects' body weights (BW); and the time from the contact until the maximum vertical component (TFZ) values were reached. The results of this study indicate that the external load on the lower extremities might successfully be controlled through a combination of steps with varying tempos over the course of the entire step aerobics programme.

The basic hypotheses of this study were to find out if there were any statistical differences in ground reaction forces, registered by means of a platform for ground reaction force measurement, in the performance of the same steps on benches of different heights and, second, different steps on benches of the same height. Therefore, the aim of this study was to define the workload to which the lower extremities were subjected in the performance of the chosen steps in order to define the key indicators of their optimal techniques based on the analyses of the components of ground reaction force exerted as the measured subjects stepped on and off the bench.

Methods

Subjects

Nine subjects, all experienced professional step aerobics instructors (5 females and 4 males) participated in this study. The females were aged 25.2±1.8 years, with body height of 171.6±8.4 cm and body mass of 59.4±7.7 kg, whereas the males were aged 27.4±3.1 years, with body height of 175.6±10.4 cm and body mass of 74.9±8.6 kg.

Kinetic variables sample

A *Kistler* platform for ground reaction force measurement (1000 Hz), positioned behind the step bench, was used to measure the ***Fx*** mediolateral component (N), ***Fy*** anteroposterior component (N), and ***Fz*** vertical component (N) of the ground reaction force.

An assessment of the kinetic parameters of the ground reaction force allowed for the determination of predictive biomechanical parameters when the subjects "took off" from the platform to step onto the bench and when they stepped off the bench, or "landed" back onto the platform, while performing two characteristic fundamental steps in step aerobics - *basic step* and *step touch*. The subjects began each single step by stepping onto the bench, always with their right foot, accompanied by the background music of 130 beats per minute. For each subject, three sets of eight executions of each step were singled out in accordance with the recommendations issued by a team of experts (long-time aerobics instructors and referees).

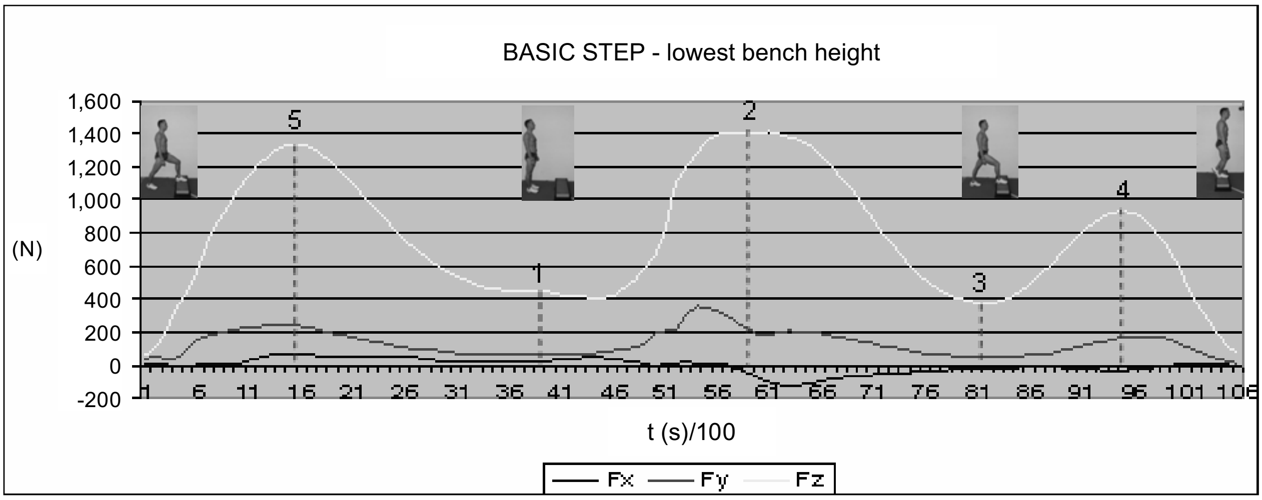


Figure 1. Characteristic ground reaction force curve in basic step with the characteristic phases of the movement.

Based on the ground reaction force signal obtained while the subjects performed one basic step, lasting approximately 1.025 seconds, onto the lowest bench height during the contact phase (subject – platform), on the sinusoidal shape of the curve, the *Fz* vertical component defined five characteristic reference points. Point (*1*) represented a phase characterized by the equal distribution of body weight between both legs, while shifting body weight to the left (take-off) leg, the force increased achieving its maximum in *2*. When the right leg was lifted onto the step bench, the pressure from the bench was relieved and the force values fell again (*3*). During the take-off and when the stepping movement was resumed, the values rose again (*4*), but they were significantly lower than the maximum values achieved during the stepping down movement onto the platform, i.e. the moment of impact absorption (*5*) due to the synchronized take-off and the act of lifting the lead leg onto the step bench.

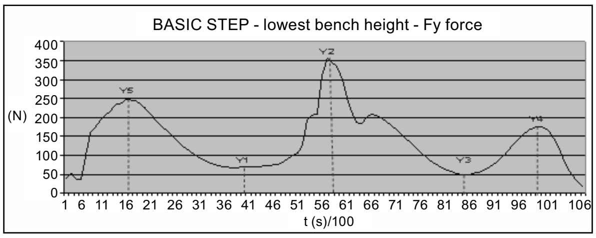
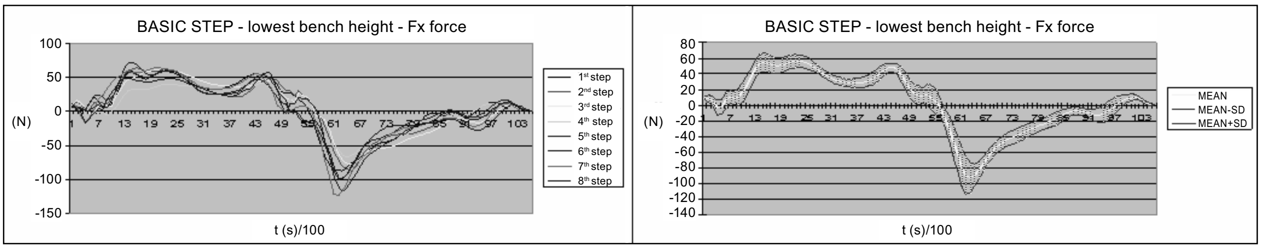


*Figure 2. Characteristic **Fy** force curve in basic step.*

In the anterior-posterior direction ***Fy*** had a characteristic shape because, unlike when walking, ***Fy*** values were believed never to be negative (Perry, 1992; Horvatin-Fučkar, 2006). The reason for this was that, during continuous workouts, the subjects did not shift body weight onto the heel of the take-off leg even when both their feet were on the platform surface. Instead, they were already in the position for the next step, with their trunk slightly bent forward. Based on the signals that were obtained, five characteristic reference points were identified. At *Y1* the values were lower because no oscillation was associated with the forward-backward movement; when body weight was shifted onto the right leg, the weight was shifted onto the front part of the foot at *Y2*. When preparing for the knee lift using the right leg, with the establishment of balance, the values at *Y3* decreased and were somewhat higher at the moment of take-off using the front part of the left foot at *Y4*; *Y5* represented the moment of impact absorption over the front part of the foot during the act of stepping off the bench onto the platform again.

The curve of ***Fx*** in the mediolateral direction had a uniform, characteristic shape because of the



Figures 3-4. Fx force curve of the performance of 8 basic step repetitions, as well as deviations from the mean.

equal distribution of body weight between both legs, thus producing less oscillation as the body strived to maintain balance. Positive values of ***Fx*** were observed in step segments when the leg was being lowered onto the platform during the impact absorption phase. During the phase when both feet were on the surface, the values approached zero, whereas they were again negative when the right leg was lifted onto the step bench. In contrast, the values returned to zero at the moment of take-off. The shapes and general characteristics of the curves for medium and peak step bench heights were identical to those obtained for the lowest height, except for the force values (especially ***Fz*** values), which were greater.

In contrast to the *basic step* performance, with the *step touch – ST*, the subjects used the left leg to support their body weight on the measurement platform and then partially shift this weight onto the right leg.

The sinusoidal shape of the ***Fz*** curve for this step also featured five characteristic points: the initial phase of the step when body weight was supported entirely by the left leg (the take-off leg) at point *1*; the partial shift of body weight onto the stepping-on leg at point *2*; the complete shift of body weight onto the take-off leg when lifting and positioning the stepping-on leg onto the step bench at point *3*; take-off from the platform using the left leg at point *4*, and impact absorption using the left leg at point *5*, while stepping off the bench onto the platform again. The difference in the obtained values between *step touch* and *basic step* revealed a smaller range between minimum and maximum values, with no steep increases or decreases due to the partial shift of body weight onto the stepping-on leg, which made the amplitude of movement during this phase of the step significantly smaller.

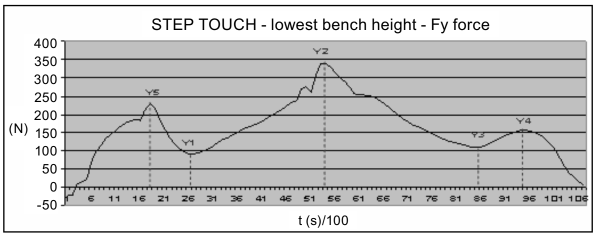


Figure 6. Characteristic Fy force curve and reference points in step touch.

The reference points on the ***Fy*** force curve were consistent with those obtained for the *basic step* not only in terms of steeper increases and decreases in values, but also in the appearance of minimum and maximum values. As opposed to the (*I*) minimum *Fy (Y1)*, the values appeared somewhat earlier due to a slight shift of body weight backwards, thus providing enough room to lower the right leg. Maximum values (*Y2*) appeared during the bouncing movement with a shallow squat because the

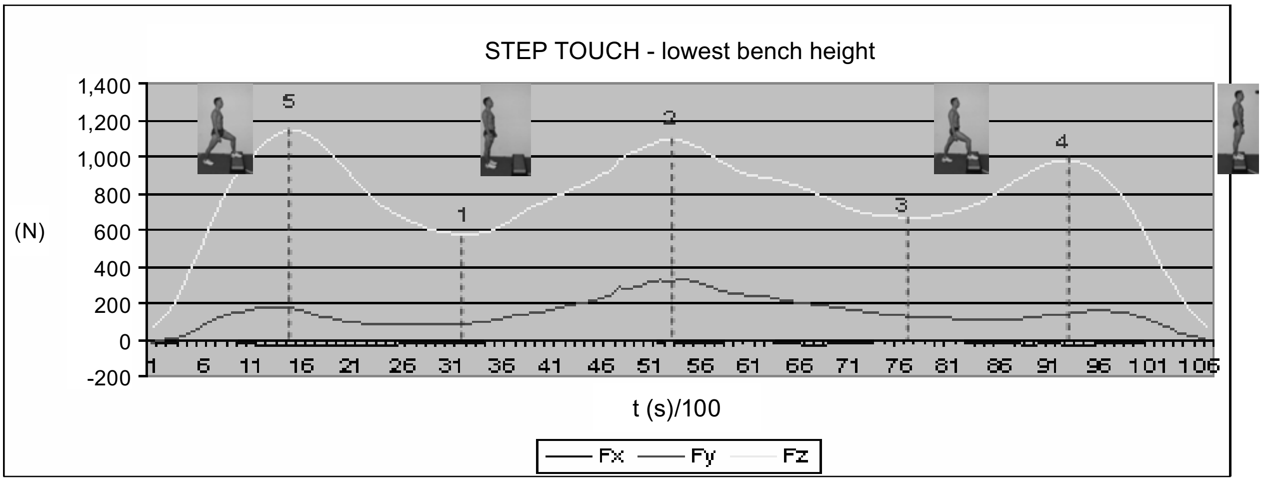
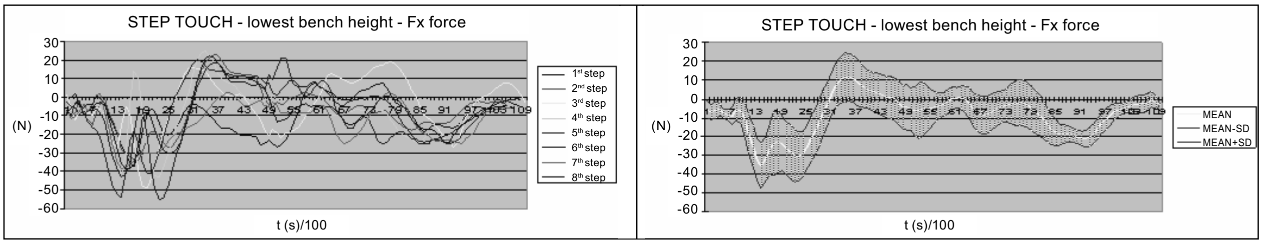


Figure 5. Characteristic ground reaction force curve in step touch with the characteristic phases of the movement.

center of gravity was projected in front of the subject with a partial shift of body weight onto both legs. When the stepping-on leg was positioned onto the step bench (*Y3*), body weight was completely supported by the take-off leg, which was used not only for the take-off (*Y4*), but also for the impact absorption (*Y5*) when stepping off the step bench onto the platform.

As expected, the vertical component of ground reaction force ***Fz*** in both observed steps displayed the greatest values (AM=.999–1.025) in the trials at the peak bench height, and the greatest dispersion of the results (SD=.026–.029). This was because the amplitudes of body movements in every observed step reached their zenith at that height. The greatest vertical ground reaction force was measured in



*Figures 7-8. **Fx** force curve of the performance of 8 step touch repetitions, as well as deviations from the mean.*

In contrast to the *basic step*, the force curves Fx in the mediolateral direction did not exhibit a uniform, characteristic shape because, while performing the *step touch* onto the platform, the subjects were constantly positioned on a smaller support surface: the toes of the take-off leg. A stable balance position was achieved immediately, with body weight distributed equally between both legs.

Results

Based on the obtained ground reaction force values, the basic statistical parameters of ***Fx*** (*mediolateral*), ***Fy*** (*anteroposterior*) and ***Fz*** (*vertical*) were calculated for the subjects performing 8 steps in three trials, at varying step bench (15, 20, 25 cm) heights: number of trials (N), means (AM); minimum (MIN) and maximum (MAX) values, and standard deviations (SD). The reason for calculating the means of the obtained signal values was that all the subjects were renowned, experienced Croatian step aerobics instructors and could therefore be expected to display model techniques when executing the observed movements.

*Table 1. Descriptive parameters of ground reaction force – **Fz** vector*

Fz	N	AM	MIN	MAX	SD
BS-15	18	.972	.933	1.018	.024
BS-20	18	1.000	.961	1.046	.025
BS-25	18	1.025	.981	1.079	.029
ST-15	18	.952	.922	1.006	.022
ST-20	18	.977	.935	1.034	.024
ST-25	18	.999	.951	1.058	.027

Legend: BS – basic step, ST – step touch (with different bench heights: 15, 20, 25 cm), ***Fz*** – vertical component of ground reaction force, N - number of trials, AM – arithmetic mean; MIN – minimum value, MAX – maximum value, SD – standard deviation.

the *basic step* (BS) at the peak bench height due to the movement structure associated with a complete shift of body weight from one leg to another. Unlike the *step touch*, during the acts of stepping off and taking off from the platform, when maximum values were achieved, weight was not removed from the take-off leg before the next step was executed.

*Table 2. Descriptive parameters of ground reaction force – **Fy** vector*

Fy	N	MEAN	MIN	MAX	SD
BS-6	18	.197	.141	.263	.036
BS-8	18	.190	.139	.249	.035
BS-10	18	.189	.137	.248	.035
ST-6	18	.203	.166	.242	.021
ST-8	18	.198	.157	.243	.026
ST-10	18	.193	.152	.235	.026

Legend: BS – basic step, ST – step touch (with different bench heights: 15, 20, 25 cm), ***Fy*** – anteroposterior component of ground reaction force, N - number of trials, AM – arithmetic mean; MIN – minimum value, MAX – maximum value, SD – standard deviation.

In both steps, the obtained values of ***Fy*** were greatest at the lowest bench height due to the change in movement structure. Namely, the subjects progressed to the next step using a continuous motion with no pauses or special preparation. In the *basic step*, the dispersion at all bench heights was greater in comparison with *step touch* (ST) due to the greater amplitude of trunk motion in a forward-backward direction.

Positive ***Fx*** vector values were achieved in the *basic step* because both feet were on the measuring platform, so the dispersion of the results was lower in comparison with *step touch*. Indeed, in *step touch*, it was harder to achieve balance due

*Table 3. Descriptive parameters of ground reaction force – **Fx** vector*

Fx	N	MEAN	MIN	MAX	SD
BS-15	18	.006	-.015	.024	.008
BS-20	18	.006	-.014	.021	.008
BS-250	18	.005	-.016	.026	.008
ST-15	18	-.019	-.033	.000	.010
ST-20	18	-.020	-.041	-.003	.010
ST-250	18	-.019	-.035	.002	.009

Legend: BS – basic step, ST – step touch (with different bench heights: 15, 20, 25 cm), ***Fx*** – mediolateral of ground reaction force, N - number of trials, AM – arithmetic mean; MIN – minimum value, MAX – maximum value, SD – standard deviation.

to the smaller support surface – the subjects were constantly positioned on the toes of the take-off leg in preparation for the next step.

The results were processed using the Wilcoxon non-parametric matched pairs test. The first section of the table suggests the results obtained in order to calculate the differences in the performances of the identical steps at varying bench heights and the second section represents the performances of various steps at identical bench heights.

*Table 4. Wilcoxon matched pairs test for **Fz** vector*

WILCOXON MATCHED PAIRS TEST for *Fz* vector				
Significance level: p<.05				
	N	T	Z	p-level
BS-15 & BS-20	**18**	**0**	**4.540725**	**.000006**
BS-15 & BS-25	**18**	**0**	**4.540725**	**.000006**
BS-20 & BS-25	**18**	**0**	**4.540725**	**.000006**
ST-15 & ST-20	**18**	**0**	**4.540725**	**.000006**
ST-15 & ST-25	**18**	**0**	**4.540725**	**.000006**
ST-20 & ST-25	**18**	**3**	**4.46865**	**.000008**
BS-15 & ST-15	**18**	**15**	**4.18035**	**.000029**
BS-20 & ST-20	**18**	**11**	**4.27645**	**.000019**
BS-25 & ST-25	**18**	**7**	**4.37255**	**.000012**

Legend: BS – basic step, ST – step touch (with different bench heights: 15, 20, 25 cm), ***Fz*** – vertical component of ground reaction force, N - number of trials, T - number of ranges, Z – values, p-level – significance level (p<.05).

In the vertical component of ground reaction force ***Fz***, at the significance level of p<.05, the statistically significant differences were observed in every test – both in the performance of identical steps at varying bench heights and in the performance of various steps at identical bench heights. It is perhaps logical to presume that exercise intensity increased by significant amounts along with the increases in bench heights. Consequently, the differences in the movement structures and the technique of performing the observed steps at identical bench heights were also statistically significant.

*Table 5. Wilcoxon matched pairs test for **Fy** vector*

WILCOXON MATCHED PAIRS TEST for *Fy* vector				
Significance level: p<.05				
	N	T	Z	p-level
BS-15 & BS-20	**18**	**91**	**2.35445**	**.018551**
BS-15 & BS-25	**18**	**79**	**2.64275**	**.008224**
BS-20 & BS-25	18	167	.52855	.597118
ST-15 & ST-20	**18**	**90**	**2.378475**	**.017385**
ST-15 & ST-25	**18**	**33**	**3.7479**	**.000178**
ST-20 & ST-25	**18**	**107**	**1.97005**	**.048834**
BS-15 & ST-15	18	135	1.29735	.194512
BS-20 & ST-20	**18**	**76**	**2.714825**	**.006631**
BS-25 & ST-25	18	127	1.48955	.136344

Legend: BS – basic step, ST – step touch (with different bench heights: 15, 20, 25 cm), ***Fy*** – anteroposterior component of ground reaction force, N - number of trials, T - number of ranges, Z – values, p-level – significance level (p<.05).

Statistically significant differences in ***Fy*** while performing identical steps at varying bench heights were observed for almost every combination due to the differences in the amplitude of movement in the upper body at peak bench heights. The statistically significant differences were not observed in tests with a large number of ranges ($T_{(BS15-ST15)} = 135$ and $T_{(BS25-ST25)} = 127$) when the difference at the same level was not statistically significant.

*Table 6. Wilcoxon matched pairs test for **Fx** vector*

WILCOXON MATCHED PAIRS TEST for *Fx* vector				
Significance level: p<.05				
	N	T	Z	p-level
BS-15 & BS-20	18	143	1.10515	.269095
BS-15 & BS-25	18	175	.33635	.736607
BS-20 & BS-25	18	124	1.561625	.118377
ST-15 & ST-20	18	160	.696725	.485975
ST-15 & ST-25	18	175	.33635	.736607
ST-20 & ST-25	18	178	.264275	.791568
BS-15 & ST-15	**18**	**0**	**4.540725**	**.000006**
BS-20 & ST-20	**18**	**0**	**4.540725**	**.000006**
BS-25 & ST-25	**18**	**0**	**4.540725**	**.000006**

Legend: BS – basic step, ST – step touch (with different bench height: 15, 20, 25 cm), *Fx* – mediolateral component of ground reaction force, N - number of trials, T - number of ranges, Z – values, p-level – significance level (p<.05).

In the component of ground reaction force ***Fx*** no statistical differences were observed in the performances of identical steps at varying bench heights. This was because the structure of movement on the measurement platform for each step was specific and uniform and could be explained using the automated stereotype of the performed movement. The statistically significant differences between different steps at identical bench heights were, as expected, observed due to the differences in step phases on the measurement platform and associated inequalities in achieving and maintaining balance.

Discussion and conclusion

The kinetic parameters of the three-component ground reaction force (***Fx*** *– mediolateral*, ***Fy*** *– anteroposterior* and ***Fz*** *– vertical direction*) allowed for the determination of predictive biomechanical parameters as the subjects stepped on and off the step bench at varying heights while performing the fundamental steps of step aerobics. The values obtained from the sample of professional aerobics instructors performing the *basic step* and *step touch* at three different bench heights were tracked and followed. Moreover, eight repetitions of each single step performed by the subjects in three sets were isolated and included in the analyses for the purposes of this study on the continuous work consisting of ten repetitions.

The basic statistical parameters of the ground reaction force were calculated for each component, and further data analyses were performed using non-parametric dependent sample statistics – the Wilcoxon matched pairs test.

The predominately positive ***Fx*** vector values were obtained for the *basic step* due to the phase when both feet were on the surface, with body weight distributed equally between both legs. This made the dispersion of the results lower than those obtained for the *step touch*, as it was harder to achieve balance due to the smaller support surface (toes) used when body weight was partially shifted to the lead leg. In the performances of identical steps at varying bench heights no statistically significant differences were observed, but, perhaps logically, the specifics of the movement structures (complete or partial shift of body weight) led to the statistically significant differences between different steps at identical bench heights.

Characteristic positive ***Fy*** values were the highest values obtained at the lowest bench height in both of the observed steps due to the change in movement structure as continuous work was being performed. The dispersion of the results was greatest in the *basic step* due to the movement structure in which body weight was distributed evenly between both legs with the greatest amplitude of the movement in the upper body (a forward-backward direction). In the performances of identical steps at varying bench heights and varying steps at identical bench heights, the expected significant differences occurred in almost all of the observed steps because the amplitudes of movement at varying heights differed with the increases in bench heights.

Vertical component ***Fz*** in the observed steps at the peak bench height, as expected, displayed the highest values with regard to the dispersion of the results because the amplitudes of body movement were greatest in each single step. The greatest values were obtained in the *basic step* because in the *step touch* performance weight was removed from the take-off leg before the next step. Statistically significant differences in both observed cases were indeed confirmed; in other words, workload intensity depended on increases in bench height and on the differences in the structure and the execution technique used for each step.

The detailed analysis of the ground reaction force signals obtained during continuous performance of the observed step aerobics steps (*basic step* and *step touch*) in several trials enabled the definition of characteristic reference points. Based on their minimal and maximal values, occurrence momentum, deviation, irregularities and the like, one can notice oscillations in performance techniques of the observed movement patterns, consequently the occurrence of additional loads, if not overloads, on the lower extremities, induced either by the redundant movements of the upper body and/or arms, or balance loss while stepping on and off the bench (Glitsch & Baumann, 1997).

The obtained maximal values of the vertical component ***Fz*** in the phase of weight shifting onto the take-off leg were the same as the ones obtained at the moment of impact amortization while stepping off the bench, which was caused by the exceptional control these experienced aerobics instructors had over their lower extremities' musculature and the movement pattern as the whole. The obtained maximal values of the component ***Fz*** were up to 2±.17 times larger than the body mass (BW) of the male instructors and up to 2.9±.12 times of the female instructors (Horvatin-Fučkar, 2006; Santos-Rocha, Oliveira, & Veloso, 2006: 1.44±.09 BW; Machado, Santos-Rocha, & Veloso, 2006: 1.2 BW). Average values of the component ***Fz*** reflected the total work load in the performance of the observed steps trials – across all bench heights they did not considerably deviate from ground reaction force values caused by the body thrust on the measurement platform. If work loads are controlled (bench height, optimal music tempo), optimal step performance technique is chosen and adequate choreography is designed, then step aerobics programmes can be considered a "safe" physical activity (Sekulić, 2001; Machado, Santos-Rocha, & Veloso, 2006), like running and walking.

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ANALIZA SILE REAKCIJE PODLOGE PRI IZVOĐENJU KORAKA U STEP AEROBICI NA KLUPICAMA RAZLIČITIH VISINA

Sažetak

Uvod

Kinetički parametri trokomponentne sile reakcije podloge (**Fx**, **Fy** i **Fz**) omogućili su utvrđivanje prediktivnih biomehaničkih parametara pri odrazu za nakorak na i pri silasku sa step klupice u izvedbi osnovnih koraka step aerobike. Klupice su bile tri različite visine. Praćenje i analiza dobivenih vrijednosti omogućili su utvrđivanje znakovitih pokazatelja mehaničkog međudjelovanja tijela i podloge te utvrđivanje značajnosti razlika promatranih parametara izvođenjem istog koraka na različitim visinama klupica i različitih koraka na istoj visini step klupice. Uz hipotezu da postoje statistički značajne razlike u komponentama sile potiska pri izvođenju istog koraka na različitim visinama step klupice i različitih koraka na istoj visini, cilj ovog rada bio je utvrditi opterećenost donjih ekstremiteta te znakovite pokazatelje koji karakteriziraju optimalnu tehniku izvođenja pojedinih koraka.

Metode

Uzorak ispitanika činilo je ukupno 9 ispitanika - 5 instruktorica i 4 instruktora step aerobike. Uzorak kinetičkih parametara izmjeren je Kistlerovom platformom za mjerenje sile reakcije podloge, uz frekvenciju uzorkovanja od 1000 Hz, postavljenom na tlo iza step klupice. Sila reakcije podloge, predstavljena trokomponentnim vektorima: ***Fx*** u *medijalno-lateralnom* (N), ***Fy*** *anterio-posteriornom* (N) i ***Fz*** u *vertikalnom smjeru* (N), registrirala je signal pri odrazu za nakorak na i pri silasku sa step klupice. S obzirom na zastupljenost oslonca na platformi za analizu su izdvojena dva karakteristična, osnovna koraka step aerobike: *osnovni korak* i *korak-dokorak*, koje su ispitanici izvodili u tri serije po osam izvođenja na tri različite visine step klupice (od 15, 20 i 25 cm). Nakon izračunavanja osnovnih statističkih parametara provedena je daljnja statistička obrada podataka neparametrijskim Wilcoxonovim testom ekvivalentnih parova za testiranje značajnosti razlike između dva zavisna uzorka.

Rezultati i rasprava

Na temelju dobivenih signala sile reakcije podloge, za komponente ***Fz***, ***Fy*** i ***Fx*** dobivene su karakteristične, ujednačene krivulje sinusoidnog oblika iz kojih je definirano 5 karakterističnih referentnih točaka s obzirom na pojedine faze koraka. Krivulje komponente ***Fx*** kod izvođenja koraka-dokoraka, bile su neujednačene, bez karakterističnog oblika zbog nemogućnosti uspostavljanja stabilne ravnoteže na mjernoj platformi uz djelomičan prijenos težine tijela na obje noge.

Izračunavanjem osnovnih statističkih parametara vertikalna komponenta sile reakcije podloge ***Fz*** u oba promatrana koraka očekivano je pokazala najveće vrijednosti (AS=,999–1,.025), kao i raspršenost rezultata (SD=,026–,029) pri izvođenju koraka na najvišim visinama step klupice, jer su i amplitude kretanja cijelog tijela na toj visini najveće. U komponenti ***Fy*** najveće vrijednosti su dobivene na najnižoj visini step klupice zbog promjene strukture kretnji, jer su ispitanici u kontinuiranom radu bez posebne pripreme i probnih pokušaja izvodili sljedeći korak.

Daljnja obrada rezultata provedenaa je neparametrijskim Wilcoxonovim testom ekvivalentnih parova radi utvrđivanja statistički značajnih razlika pri izvođenju istog koraka na različitim visinama te različitih koraka na istim visinama step klupice. U vertikalnoj komponenti sile reakcije podloge ***Fz*** na razini značajnosti od $p<,05$) u obje varijante dobivena je očekivano statistički značajna razlika. Statistički značajne razlike u komponenti sile ***Fy*** nisu se očekivano pojavile u svim varijantama izvođenja. Izostale su u testovima s velikim brojem sume rangova ($T_{(BS15-ST15)} = 135$ i $T_{(BS25-ST25)} = 127$) kada se na istoj razini dobivena razlika ne može smatrati statistički značajnom.

Zaključak

Zbog specifičnosti kretnih struktura (bilo potpunog ili djelomičnog prijenosa težine tijela na obje noge) analizom dobivenih rezultata potvrđene su očekivane razlike između izvođenja istih koraka na različitim visinama step klupice, kao i između različitih koraka na istoj visini step klupice. Izvođenjem koraka na većim visinama step klupice povećani su ukupni intenzitet i učinkovitost vježbanja zbog znatno većih amplituda kretanja cijelog tijela, a time je i ukupno opterećenje na koštano-zglobni sustav pri penjanju na klupicu i silasku s nje znatno veće. Iz analize dobivenih rezultata pri izvođenju različitih koraka na istoj visini step klupice vidimo da su statistički značajne razlike primarno uvjetovane razlikama u strukturi i tehnici izvođenja promatranih koraka u cjelini, kao i pojedinih njihovih faza. Kreiranje takvih koreografija u step aerobici kojima je cilj očuvanje zdravlja vježbača treba koncipirati na izmjenjivanju različitih kretnih struktura na optimalnoj visini step klupice (na najnižoj i srednjoj visini). Na najvišoj visini step klupice opterećenja su znatna zbog čega se vježbači sporije adaptiraju na novu kretnu strukturu i teže zadržavaju pravilnu tehniku izvođenja, a opterećenost koštano-zglobnog sustava donjih ekstremiteta izuzetno je velika. Dobivene maksimalne vrijednosti vertikalne komponente ***Fz*** su u fazi prijenosa težine tijela na odraznu nogu podjednake kao i pri amortizaciji pri silasku sa step klupice, što je uvjetovano izuzetnom kontrolom muskulature donjih ekstremiteta i pokreta u cjelini iskusnih dugogodišnjih voditelja step aerobike. Dobivene maksimalne vrijednosti komponente ***Fz*** su do

2±,17 puta veće od mase tijela kod instruktora te i do 2,9±,12 puta veće kod instruktorica (Santos-Rocha et al., 2006: 1,44±,09; Machado et al., 2006: 1,2). Prosječne vrijednosti komponente ***Fz*** reflektiraju koliko je ukupno opterećenje pri izvođenju zadanih ponavljanja promatranih koraka te pri svim visinama znantno ne odstupaju od sile reakcije podloge koju vježbači uzrokuju potiskom tijela na mjernu platformu. Kontrolom opterećenja (visinom klupice, izborom primjerenog tempa glazbe), optimalnom tehnikom izvođenja pojedinih koraka te primjerenim koreografijama step programe možemo učiniti "sigurnim" aktivnostima (Sekulić, 2001; Machado et al., 2006), kao što su trčanje i hodanje.