Original Article

Categorization of impact forces during rebound exercise class

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ABSTRACT

Rebounding fitness class became popular due to the supposed capacity of minimize the impact forces on the body of participant. However, no studies about impact forces during rebound exercise class have been found. Thus, the aim of this study was to assess the impact forces produced during a series of traditional rebounding exercises and present a categorization based on impact force parameters. Sixty instructors of rebound exercise performed various rebound exercises on a standard mini-trampoline, which was optimized with six load cells. The load cells were used to assess the impact parameters (peak and loading rate of the ground reaction force). One-way ANOVA was used to compare the exercises (α = 0,05). As results, we noted that when peak force is used to assess impact, the most of the rebound exercises are classified as low (<3xPC) and high impact (>4xPC); while when rate loading is used, most of the exercises are considered as moderate (20-30x PC/s) and high impact (<20x PC/s). Thus, each evaluated impact parameter results in a different rebound exercise categorization. The selection of progression of rebounding exercises during a fitness class should take in consideration the peak and loading rate values and its possible effects on the musculoskeletal system. **Keywords:** Aerobic exercises; Peak of force; Loading rate; Trampoline.

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INTRODUCTION

Rebound exercise classes are designed to improve cardiovascular condition based on pre-choreographed group sessions in which each participant performs exercises on a mini-trampoline for approximately 45 minutes (Smith et al.,1995; Furtado, Simão & Lemos, 2004; Maharaj & Nuhu, 2015). Practicing rebound exercises class provides the same benefits as regular aerobic exercises, producing a notable reduction in body fat and improvement in cardiovascular health (Smith & Bishop, 1988; Smith et al., 1995; Furtado, Simão & Lemos, 2004; Grossl et al., 2008; Maharaj & Nuhu, 2015; Maharaj & Nuhu, 2016). However, rebound fitness class stands out from other gymnastic modalities due to the fact it produces less impact forces on the musculoskeletal system when compared to the same exercises performed with the feet making direct contact with the ground (Smith et al., 1995; Furtado, Simão & Lemos, 2004).

In general, impact can be defined as a force that results from a collision of two objects in a short period of time (Nigg & Herzog, 1999; Zatsiorski, 2001; Majaraj & Nuhu, 2016). High impact values originating from the initial contact of the foot with the ground may be one of the possible causes of the exacerbated occurrence of injury to the structures responsible for absorbing impact forces during aerobic exercises, such as bones, cartilage and joints (Francis, Francis & Welshons-Smith, 1985, Miller, 1990; Dufek & Bates, 1990). Equally, low intensity and high frequency impact is known to be associated with beneficial effects, such as increased bone mineral rate, and is recommended in the treatment and prevention of osteoporosis and osteopenia (Rubin et al, 2001). Therefore, the evaluation of the impact forces during rebounding exercise classes can be seen to be of great importance to the health of the participants, because it can help the instructor prescribe the intensity of impact forces during the classes, and so provide maximum benefits and avoid undesirable negative adaptations.

Although the reduced impact produced during the rebound exercise classes is one of the its most attractive characteristics for both practitioners and instructors, most authors have focused their investigations on the physiological characteristic involved (Smith et al., 1995; Furtado, Simão & Lemos, 2004; Grossl et al., 2008; Maharaj & Nuhu, 2015). Consequently, the intensity of each part of the rebound exercise class has been prescribed based exclusively on physiological parameters such as heart rate and subjective effort. The problem with this is that there is not always a perfect relationship between one physiological variable (e.g. heart rate) and another biomechanical variable (e.g. impact force) during aerobic exercise. Thus, while the exercise could be suitable for cardiovascular health it may be very damaging to the bone and ligament structures, for example.

Despite this situation, no study was found in the literature that assesses the impact on the human body of each exercise or part of a rebound exercise class. Thus, the magnitude of the impact forces at work during such classes is completely unknown. Considering the scarcity of data on the topic and the need to provide scientific bases for the prescription of rebound exercise classes by physical education professionals, the aim of this study is to assess the impact forces produced during a series of traditional rebound exercises and present categorization based on impact force parameters such as peak and loading rate of the ground reaction force (GRS).

MATHERIAL AND METHODS

Participants

This study was classified as an observational descriptive study of impact forces during the rebound exercise classes. The study sample was intentional, extracted from the population of physical education teachers accredited and licensed in the same Brazilian Rebound Exercise Program. Sixty instructors of both sexes, aged (28.5 ± 5.9) years, height (170 ± 8) cm, and body mass (62.9 ± 9.8) kg participated. The inclusion criteria were that the instructors should be accredited in the rebound exercise program and have at least six-month experience teaching the modality. The exclusion criteria were having an untreated lesion in the skeletal muscle system of the lower limbs within the last 6 months and having any acute or chronic cardiorespiratory dysfunction that could prevent the performance of moderate or high-intensity exercise. This study was approved by the Ethics Committee of the Federal University of Rio Grande do Sul (Certificate of Presentation for Ethical Consideration (CAAE) # 40701214.2.0000.5347). Participants signed a free and informed consent form prior to beginning the study and were informed that they could stop participating in the study at any time.

Measures
The impact parameters (peak and loading rate of the ground reaction force) were obtained by load cells. Load cells were attached to the base of each of the six legs on a standard mini-trampoline, as used in Jump Fit class (Figure 1). The 250 kg load cells (HBM, model PW10D1) were connected to a computer using a 16 bits A-D converter (Computer-boards) with 500 Hz sampling rate.

Figure 1. Rebound exercise mini-trampoline with attached load cells

Assessment protocol
The participants were asked to execute the movements in the same way they would conduct the activity in the classroom, always beginning the movement with the left leg as recommended by rebound exercise program, with music set a pace of 140 bpm. According to the classification provided by the brazilian rebound exercise program, the exercises conducted belong to either Family I or Family II. The Family I exercises involve the constant transfer of weight from one foot to the other, such as tcha-tcha, jogging, simple hop, sprint, skip, hamstrings curl and double gallop. The Family II exercises involve the simultaneous contact of both feet with the mini-trampoline, such as basic, jumping jack, split jack, double kangaroo and double twist. An image of assessed rebound exercises can be found in the Figures. 2 and 3. Each exercise was performed for two minutes. The first sixty seconds were used to reach a stable cycle of repetitions. The data used in the analysis were obtained from the first 45 seconds of the second minute.


TAP right
TAP left
Jogging right
Jogging left
Running right
Running left
Gallop right
Gallop left
Tcha Tcha right
Tcha Tcha left
Sprint
Skip right

Skip left

High knee right

High knee left

Hamstring Curl right

Hamstring Curl left

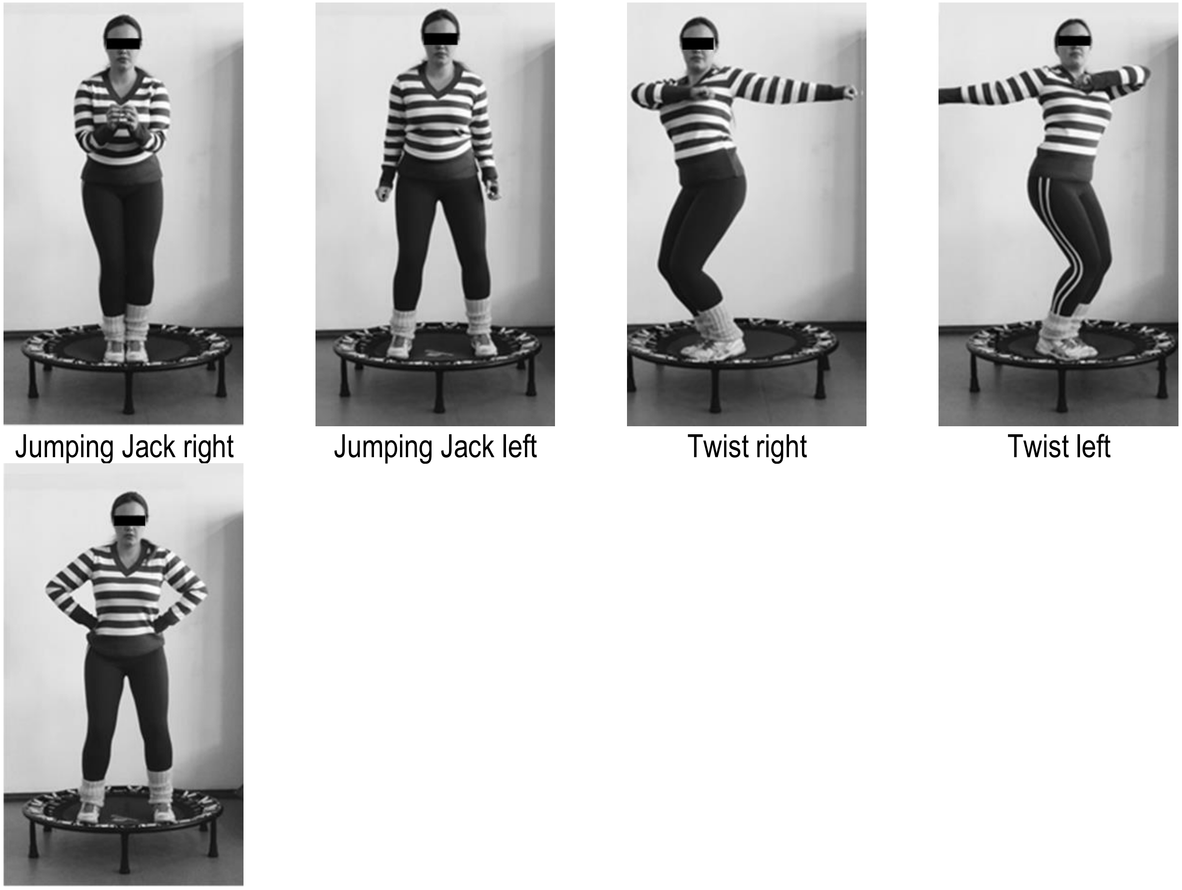
Figure 2. The family I exercises. 2a) TAP right, 2a), TAP left; 2b); Jogging right, 2b), Jogging left; 2c) Running right, 2c) Running left; 2d) Gallop right, 2d) Gallop left; 2e) Tcha Tcha right, 2e) Tcha Tcha left; 2f) Sprint, 2g) Skip right, 2g) Skip left; 2h) High knee right, 2h) High knee left; 2i) Hamstring Curl right, 2i) Hamstring Curl left

Split Jack right

Split Jack left

Kangoroo right

Kangoroo left



Jumping Jack right Jumping Jack left Twist right Twist left

Basic Jump

Figure 3. The family II exercise. 3a) Split Jack right, 3a) Split Jack left; 3b) Kangoroo right, 3b) Kangoroo left; 3c) Jumping Jack right, 3c) Jumping Jack left; 3d) Twist right, 3d) Twist left; 3e) Basic Jump

Data Analysis

The data from each load cell were added together to produce a single resultant force curve, which was normalized by the individual's weight. During the 45 seconds of the performance selected for analysis, the values corresponding to at least 20 consecutive resultant force peaks were considered. For this, three situations were established: (1) when the exercises were performed alternating the left and right lower limbs and there was no significant difference between the two in terms of peak force, in which case the mean of each subject/exercise was calculated using 10 peaks from the left and 10 peaks from the right; (2) when the exercises were performed alternating the left and right lower limbs and there was a significant difference between the two in terms of peak force, in which case the mean of each subject/exercise was calculated using 20 peak forces from each side; (3) when the exercises were performed using both lower limbs simultaneously with more than one peak force in each cycle, in which case the mean of each subject/exercise was calculated using a sufficient number of cycles to ensure that 20 consecutive peak forces were obtained.

The loading rate was calculated in the same situations used to determine the peak forces, using the ratio between the normalized maximum force value (peak force) and the time interval between the start and the peak of the force in each cycle.

Statistical analysis
To compare the averages of the variables between the left and right sides in the different exercises, the student t test for paired samples was used. When there was no difference, the mean value (n=20), left side (n=10) and right side (n=10), was used to represent the variable in the exercise for each individual. When there was a difference, the highest value was used to represent the variable in the exercise for each individual.

One-way ANOVA was used to compare the exercises and Bonferroni's post hoc test was used to identify any differences. In this analysis SPSS software (version 11) was used, and the level of significance was set at α = 0.05 in all tests.

RESULTS

The exercises are ordered in two columns according to the peak force values and the loading rate (Table 1). The order in which each exercise appears in each column is determined by the mean values obtained for each variable. The statistical differences are represented by letters, where different letters indicate significant differences between exercises. The exercises were grouped in three categories according to the peak force values and force application rate: low, moderate and high impact. The exercises within a determined impact category can be seen to change according to parameter used (Table 2).

Table 1. Peak and loading rate of ground reaction force during the rebound exercises. Mean ± SD

Exercises	Peak (x PC)	Exercises	Loading rate (x PC/s)
Tap	1,3 ± 0,6[a]	*Tap*	10,1 ± 5,4[a]
Sprint	2,0 ± 0,3[a]	Jogging	16,5 ± 3,9[a]
Jogging	2,3 ± 0,4[ab]	Running	17,9 ± 4,1[a]
Running	2,4 ± 0,4[b]	*Tcha-tcha*	20,3 ± 5,1[ab]
Tcha-tcha	2,6 ± 0,5[bc]	*S*imple hop	23,4 ± 4,6[bc]
*S*imple hop	2,9 ± 0,4[c]	*Sprint*	23,6 ± 5,9[bc]
Double gallop	3,3 ± 0,4[d]	Double gallop	27,8 ± 6,0[c]
Skip	3,5 ± 0,6[d]	Skip	34,0 ± 8,0[d]
Double kangaroo	4,3 ± 0,7[e]	Double kangaroo	46,4 ± 8,9[e]
Double jumping jack	4,3 ± 0,5[e]	Double twist	47,5 ± 7,7[e]
Double twist	4,4 ± 0,5[e]	Simple Split Jack	49,8 ± 9,3[e]
Hamstring curl	4,4 ± 0,5[e]	Double Split Jack	49,9 ± 8,9[e]
Simple jumping jack	4,4 ± 0,5[e]	Simple jumping jack	50,1 ± 9,7[e]
Double Split Jack	4,4 ± 0,5[e]	Basic Jump	50,5 ± 10,9[e]
Simple Split Jack	4,5 ± 0,5[e]	Double jumping jack	51,5 ± 10[e]
Basic Jump	4,5 ± 0,5[e]	Hamstring curl	51,6 ± 14,7[e]

Different letters indicates significant differences (p<0.05).

Table 2. Categorization of the rebound exercises based on peak and loading rate of ground reaction force

	Peak	Loading rate
Low impact	< 3x PC	< 20x PC/s
	Tap	*Tap*
	Sprint	Jogging
	Jogging	Running
	Running	
	Tcha-tcha	
	Simple hop	
Moderate impact	3-4x PC	20-40x PC/s
	Double gallop	*Tcha-tcha*
	Skip	Simple hop
		Sprint
		Double gallop
		Skip
High impact	> 4x PC	> 40x PC/s
	Hamstring curl	Hamstring curl
	Double kangaroo	Double kangaroo
	Double twist	Double twist
	Simple Split Jack	Simple Split Jack
	Simple jumping jack	Simple jumping jack
	Double jumping jack	Double Split Jack
	Basic Jump	Double jumping jack
		Basic Jump

DISCUSSION

Rebounding exercise class is an aerobic gymnastic modality that stands out from others due to the apparently lower impact force produced by the contact between the practitioner's foot and the elastic material of the mini-trampoline during the classes. Despite the possible benefit and damage that impact may generate on the structures responsible for its abortion in the human body, no study that investigated the impact forces during rebound exercises classes was found in the scientific literature. In order to fill this gap, the aim of this study is to assess rebound exercises based on peak force values and loading rate and categorize them accordingly.

The results for peak force show that some rebound exercises, in which at least one foot maintains contact with the trampoline, present peak force values lower than or vary close to 2x body weight (BW), as in the exercises Jogging (1.3x BW), Tap (2.3x BW) and Sprint (2x BW) (Table 1). It is interesting to note that similar values have been found by various authors who used force platform to assess impact during gymnastic movements and gait (Michaud et al., 1993; Richard & Veatch, 1993).

In aerobic gymnastic for example, values below 2x BW were found by Michaud et al (1993) during skip movements. Similarly, peak force values between 1.96 and 2.62 x BW were reported by Ricard and Veatch (1994) for aerobic dance jumps in the aerobic dance modality. Ribeiro and Mota (1994) assessed the peak force behavior during stepping in gymnastic at three different cadences. The values presented were 1.09x BW for the 130 bpm cadence, 1.11x BW for 140 bpm cadence and 1.16x BW for the 160 bpm cadence. It should be noted that those values were similar to those obtained during movements carried out in "Step Training", such as quick walk or the jogging (Farrington & Dyson, 1995; Wieczorek & Duarte; 1997; Dixon, Collop & Batt; 2000). The above comparison shows that some rebound exercises present impact forces that are similar to those of other gymnastic movements normally classified in the literature as being of low impact, and can thus be used to provide the practitioner a proper transition between one modality and another while maintaining the same level of impact. However, the results show most of the impact forces produced by the exercises assessed in the present study are more similar to values that have been classified in the literature as being of high impact (Tables 1 and 2).

The high levels of peak force obtained in the evaluated exercises can be explained by the different landing strategy involved in landing on the trampoline compared to the hard floor. As the landing technique consist in jumping and pushing against the elastic surface, greater vertical force values are applied during rebound exercise class in an attempt to increase the normal force and achieve better performance in the movements.

When the loading rate was used as the parameter to assess the impact, the results of the present study indicated that the rebound exercises produce lower values than those observed in other movements reported in the literature. It was found, for example, that the values reported for all the assessed exercises were lower than those found by Miller (1990) for running at a speed of 5 m/s (113 x BW/s).

Another noteworthy aspect is that the lowest loading rate values are obtained exclusively by the exercises classified as belonging to Family I by the company where the participates of this study was credited. Thus, it can be inferred that performing foot-swap exercises or jumping with two feet simultaneously influences the level of the force application rate at extreme magnitudes. However, as the application rate values increase, as occurs in the exercises classified in the present study as "moderate" (Table 2), the exercises in Family I and II appear together in the same category. In practice, this means that modulating intensities in each phase of the session based solely on the criteria of pertaining to Family I or II does not appears to be the most suitable when the objective of the session is in some way related to the impact.

The results presented are important from the practical point of view, since, although the magnitude of the forces involved and the loading rate of those forces were considered important in relation the risk of muscular-skeletal injury, both act differentially on the structures of the human body. Data has shown, for example, that the force loading rate may be a better indicator of the absorption of mechanical load than the peak force value (De Wit, De Clercq & Lenoir, 1995; Dixon, Collop & Batt, 2000).

Mechanical trials conducted *in situ* to evaluate the maximum capacity of structures, demonstrate that forces applied "rapidly" tend to break ligaments and tendons, while those increased gradually lead to avulsion fracture (Whiting & Zernicke, 2001). Thus, it appears that if the force is applied at high rates, structures such as ligaments and tendons are most likely to be affected, while the bones are more likely to be damaged when the force application rate is low.

Although the force values associated with the analysed exercises may be far lower than those necessary to rupture these tissues, micro-injuries may occur in cyclical activities, even when the loads involved are low

(Nordin & Frankel, 1988). By contrast, the magnitude of the impact forces is the fundamental factor characterizing joint cartilage injuries, mainly when combined with reduced contact areas between adjacent bones (Nigg & Herzog, 1999).

Although the mean scores of some exercises may statically vary, the difference may not necessarily be biologically significant or clinically relevant. When, for example, the peak force of the *sprint* exercise is compared with that of that running and the latter with the simple hop, the differences observed to were 0.4 and 0.5 x BW, respectively. Even though the mean scores are statistically different, there is no evidence in the literature to show that differences of this order represent important adaptations to the muscular-skeletal structures.

Given the above and the detected statistical differences, the present study suggests one classification based on the peak force and another on the force loading rate (Table 2). It is hoped that this results represent a first step towards the prescription of exercises the takes into account biomechanical parameters such as impact forces, since they describe the behaviour of each exercise based on two components of those impact forces. However, it is not yet possible to associate the knowledge of the effects of each of these components on the muscular-skeletal structures with the aims sought in each phase of the session. To achieve this, it is necessary to conduct more studies using this type of impact classification to modulate the intensity of the sessions and assess their effects on the human body.

From the practical point of view, the findings of this study suggest that modulating the effect of rebound fitness exercises based on the determined group or family to which they belong does not appear to be appropriate when the aim of the training program is associated to adaptations that produce impact forces in the human body, be they positive or negative.

We believe this study represents a first step towards assessing and classifying the impact produced during rebound exercise. There is little information available on separate effects of peak force and force rate on the structures in human body responsible for absorbing those impacts, and therefore caution is necessary when prescribing such exercises. Further studies investigating the influence of different exercises and their effect parameters on the muscular skeletal structures should be carried out in order to advance this line of research.

CONCLUSION

The classification of rebound exercise exercises based on impact forces produced by those exercises differs according to the parameter used in the assessment. The peak force presented higher values than those reported in the literature for aerobic gymnastics and gait movements, while the rate of applied force presented lower values than those reported for some movements, such as jogging.

DECLARATION OF CONFLICT OF INTEREST

The authors report no conflict of interest.

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