ORIGINALIA

ACCEPTED: January 2018
PUBLISHED ONLINE: February 2018
DOI: 10.5960/dzsm.2018.318
Witassek C, Nitzsche N, Schulz H. The effect of several weeks of training with mini-trampolines on jump performance, trunk strength and endurance performance. Dtsch Z Sportmed. 2018; 69: 38-44.

Witassek C[1], Nitzsche N[1], Schulz H[1]

The Effect of Several Weeks of Training with Mini-Trampolines on Jump Performance, Trunk Strength and Endurance Performance

Der Effekt eines mehrwöchigen Trainings mit Minitrampolinen auf Sprungkraft, Rumpfkraft und Ausdauerleistungsfähigkeit

1. TECHNISCHE UNIVERSITÄT CHEMNITZ, *Fakultät für Human und Sozialwissenschaften, Institut für angewandte Bewegungswissenschaften, Chemnitz*

Summary

› **The aim of the present study** was to examine the effect of a jumping-fitness training on mini-trampolines on endurance capacity, trunk strength and reactive jump performance. 21 healthy, untrained volunteers were separated in an intervention group (n=12: age 22±4 years, BMI 22.6±2.6kg/m^2) and a control group (n=10: age 25±3 years, BMI 22.8±4.3kg/m^2).

› **The participants** in the intervention group completed an eight-week standardized jumping training on mini-trampolines with three training-sessions (TS) per week on average. The control group received no intervention. Pre- and posttests included a treadmill-test and a jumping-test to examine reactive jump performance (drop jump). Furthermore trunk strength was measured using an isometric maximum test. Additionally heart rate (HR), energy expenditure and perceived exertion (BORG 6-20) were monitored during all TS.

› **After eight weeks** of intervention jumping group showed significant increases in running speed at V4 and isometric maximum strength in trunk extension. Changes in jump performance were not significant (p>0.01). A nonsignificant group*time interaction was found (p>0.05). Control group showed no significant increase in all parameters (p>0.05). Participants of intervention group trained at 83±4% compared to their maximum heart rate. The mean energy expenditure was 9.7±2.5kcal/min during TS. The mean perceived exertion was 14.2±2.2 (somewhat hard/hard) and decreased over intervention period.

› **The results show,** that standardized jumping training on minitrampoline is a vigorous conditioning training and should be control on the effectiveness.

Zusammenfassung

› **Ziel der vorliegenden Studie** war es, die Auswirkungen eines mehrwöchigen Jumping-Fitness-Trainings auf Minitrampolinen auf die Ausdauerleistungsfähigkeit, Rumpfkraft sowie reaktive Sprungkraft zu untersuchen. Dafür wurden 21 gesunde, untrainierte Probanden einer Interventionsgruppe (N=12: Alter 22±4 Jahre, BMI 22,6±2,6kg/m^2) und einer Kontrollgruppe (N=9: Alter 25±4 Jahren, BMI 22,7±4,6kg/m^2) zugeordnet.

› **Die Probanden** der Interventionsgruppe erhielten durchschnittlich dreimal wöchentlich über acht Wochen ein standardisiertes Sprungtraining auf Minitrampolinen. Die Kontrollgruppe erhielt keine Intervention. Prä- und Post-Tests beinhalteten einen Laufbandstufentest, reaktiven Sprungtest (Drop Jump), isometrischen Rumpfkrafttest sowie Messung der Körperzusammensetzung. Zusätzlich wurden die Herzfrequenz (Hf), der Kalorienverbrauch und die subjektive Anstrengung (BORG 6-20) während der Trainingseinheiten erfasst.

› **Es zeigten sich** nach acht Wochen Intervention signifikante Verbesserungen der Laufleistung bei V4 und der isometrischen Maximalkraft der Rumpfextension (p<0,01) in der Jumping Gruppe. Die Veränderungen der Sprungleistung war nicht signifikant (p>0,01). Die Kontrollgruppe zeigte keine signifikanten Veränderungen (p>0,05). Ein signifikanter Interaktionseffekt zwischen Gruppe und Zeit lag nicht vor (p>0,05). Die Interventionsgruppe trainierte im Durchschnitt bei 83±4% der Hf_{max} und verbrannte 9,7±2,5kcal/min. Die subjektive Anstrengung lag im Mittel bei 14,2±2,2 (etwas anstrengend/anstrengend) und reduzierte sich über den Interventionszeitraum.

› **Die Ergebnisse zeigen,** dass ein standardisiertes Sprungtraining mittels Trampolinen ein intensives Konditionstraining ist, welches durch weitere Untersuchungen auf Effektivität hin zu untersuchen ist.

KEY WORDS:
Trampoline Exercise, Jumping, Endurance, Trunk Strength

SCHLÜSSELWÖRTER:
Trampolin-Fitness, Springen, Ausdauer, Rumpfkraft

CORRESPONDING ADDRESS:
Dr. Dr. Nico Nitzsche
Technische Universität Chemnitz
Institut für Angewandte Bewegungswissenschaften
Thüringer Weg 11, 09126 Chemnitz
: nico.nitzsche@hsw.tu-chemnitz.de

Introduction

The fitness industry in Germany is experiencing continual market growth. According to the DSSV (German Employers' Association in Fitness and Health Facilities), the number of memberships in fitness studios rose from 9.46 to more than 10 million in 2017 (16). The Second B2B Survey of Fitness Trends in Germany showed that an increasing number of highly qualified offers, fitness programs for senior citizens, sports programs to promote health in the workplace, training for weight reduction, and guided group fitness programs have established themselves within the top 5 trends available on the German fitness market. In 2016, fascia training, jumping, suspension training, and deepWORK® (functional group training) were the most commonly mentioned personal fitness trends (19). In 2017, jumping was ranked among the German top 40 (20).

Jumping-Fitness is a workout in which various slow, fast, and intensive jumps are combined with classical aerobic steps on a mini-trampoline accompanied by music. In contrast to conventional trampoline jumps, here the upper body is bent over and held still, while only the legs carry out the jumping movements. This form of trampoline workout is considered to be gentle on joints with high energy expenditure, and is presumed to be effective for training the abdomen, legs, buttocks, and deep back muscles. It is also considered effective for endurance training (24). Existing studies on trampolining show that biomechanical load while jumping on a trampoline is lower than during jogging at the same heart rate (4). It has also been found that, for comparable oxygen intake, the physical work on a trampoline is 68% greater than on a treadmill. McGlone et al. (2002) found that jumping on a mini-trampoline with comparable perceived exertion as during running resulted in similar cardiopulmonary load for both activities (32). The measured heart rates, maximum oxygen intake (VO_2max), and energy expenditure (9.45±1.75kcal/min) were analogous. Burandt et al. (2016) also found similarly high values for energy expenditure (6). Sahin et al. (2016) showed that regular aerobic training on a mini-trampoline was more effective in improving VO_2max than jogging. However, heart rates recorded during training on the mini-trampoline were 15% higher than during running (37). In addition, regular training on a mini-trampoline significantly increased jump height (2, 25, 37). Compared to a running group and a control group, trampolining resulted in a significant reduction of body fat (1, 37). Currently, there is no evidence of that trampolining effects back strength (25). Studies on the effects of trampolining as a fitness program are rare, and the results are difficult to compare due to varying jump techniques. Some of the studies implemented solely intensive jogging, which is only part of the jumping workout. So far, no meaningful effects on trunk strength (anterior and lateral abdominal muscles) have been found. Based on current findings, we hypothesized that eight weeks of standardized, guided jumping training on a mini-trampoline results in significant increases in aerobic capacity, trunk strength, and reactive jumping power. The purpose of the present study, therefore, was to examine the effects of an eight-week training program on these physiological dimensions.

Methods

Sample

21 healthy subjects unaccustomed to the training regimen used in this study were included. Subjects were assigned to an intervention group (IG, N=12: 10 female, 2 male; 22±4 years, BMI 22.6±2.6kg/m²) or a control group (CG, N=9: 6 female, 3 male; 25±4 years, BMI 22.7±4.6kg/m²).

Experimental Setup and Training Regimen

An incremental test of aerobic capacity on a treadmill, as well as tests for reactive jumping power, trunk strength, and body composition were conducted pre and post the eight-week intervention. The control group did not receive any specific intervention, and the intervention group was exposed to a jumping exercise regimen (three times per week) on a mini-trampoline guided by an instructor. Post-tests were conducted during the same time of day as the pre-test within one week of completing the intervention period.

Trampoline exercise sessions were standardized using an instructional video and carried out using a mini-trampoline (Jumping® Profi Standard Plus, München, Germany). The 19-minute video (CYBERMOVES-Clip, CYBERCONCEPT, Münster, Germany) was accompanied by seven different songs. Each training session consisted of a 2:52 minute warm-up with mobilisation and low-impact jumps, a 14:30 minute main section with low and high impact jumps, and a one-minute cool-down with low intensity jumps.

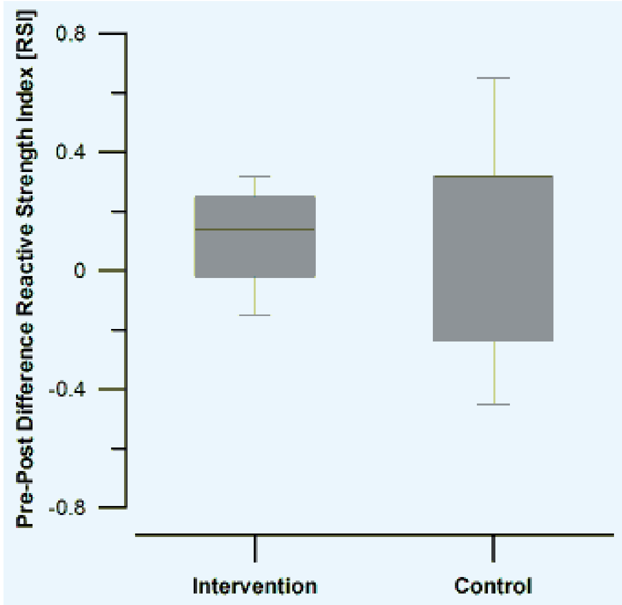

Figure 1

Mean differences and SD of RSI for the intervention and control groups.

The first session (S1) was used for subjects to become accustomed to the mini-trampoline and to practice different types of jumps. Starting with the second session (S2), the training regimen was carried out under the supervision of a certified instructor. In total, IG completed 24 sessions (S1-S24).

Data Collection Procedures

The following tests were conducted before (PRE) and after (POST) the eight-week intervention period:

Aerobic capacity was defined as the treadmill speed ($m*s^{-1}$) at blood lactate levels of $2mmol*l^{-1}$ (V2) and $4mmol*l^{-1}$ (V4), with the treadmill set at 1% incline, starting at $6km*h^{-1}$ with increments of $2km*h^{-1}$ applied every 4 minutes. V2 and V4 were calculated by linear interpolation of recorded blood lactate levels.

Trunk strength on extension (kg) and flexion (kg) was assessed using tests of isometric maximal force (TONUS EasyTorque, Zemmer, Germany). The maximum isometric strength was measured. The maximum of three repeated trials was used for analysis and normalized to body weight.

Jump force was assessed using a drop jump test (no arm involvement, 30cm initial height) onto a contact mat (SMARTJUMP, Fusion Sport, Nottingham, UK) to determine contact times (CT) and jump height (JH). Given CT and JH, the index of reactive strength (RSI = JH/CT) was calculated (35). Out of five repeated jump trials, the trial with minimum CT was chosen for further analysis.

Body composition was quantified using bioelectric impedance analysis (BIA) using a body composition analyzer (TANITA BC-418 MA, Illinois, USA). It were calculated the body weight, body fat and muscle mass.

In addition to PRE and POST test recordings, heart rate (HR), energy expenditure, and physical exertion were assessed in each of the 24 trampoline training sessions (S2-S24).

Table 1

Mean. SD. range. normalized pre-post difference (%). statistical significance (*p<0.01) and effect size of the collected variables. BMI= Body Mass Index; BF= body fat; MM= muscle mass; V2= running speed at blood lactate of 2mmol l-1; V4= running speed at blood lactate of 4mmol l-1; RSI= reactive strength index; CT= contact time; JH= jump height.

		INTERVENTION GROUP				CONTROL GROUP			
		PRETEST	POSTTEST	%	d	PRETEST	POSTTEST	%	d
Anthro-pometry	BMI	22.6±2.6kg/m²	22.4±2.5kg/m²	-0.9	0.08	22.7±4.6kg/m²	22.8±4.7kg/m²	0.4	0.02
		(17-26.7)	(17.1-26.7)			(16.3-30)	(16.7-29.6)		
	BF	27.6±5.9%	26.1±5.4%	-5.40	0.27	22±9%	21.7±8.1%	-1.4	0.04
		(20.3-35.6)	(18.4-35.1)			(12.1-36.4)	(12.2-34.3)		
	MM	24.8±3.1kg	25.2±3.3kg	1.60	0.12	27.9±8kg	28.1±8.4kg	0.7	0.02
		(21.6-32.6)	(21.3-33.1)			(19.3-42.3)	(19.7-42.3)		
Endurance performance	V2	6.4±1.2km/h	6.8±0.9km/h	6.30	0.38	6.0±1.9km/h	6.4±1.3km/h	6.7	0.25
		(4.9-8.8)	(5.8-8.3)			(2.9-8.4)	(4.3-8.4)		
	V4	8.2±1.4km/h	8.7±1.4km/h	6.10	0.36*	7.9±1.6km/h	8.1±1.3km/h	2.5	0.14
		(6.5-10.9)	(6.8-10.8)			(4.9-10.2)	(6.2-10.4)		
Reactive jump performance (drop jump)	RSI	0.9±0.24	1.01±0.23	12.20	0.47	0.74±0.36	0.75±0.3	1.35	0.03
		(0.6-1.33)	(0.67-1.37)			(0.25-1.46)	(0.19-1.26)		
	CT	192.5±24.1ms	184.5±28.3ms	4.20	0.3	228.1±48.5ms	236.9±62.6ms	-3.9	0.16
		(159-232)	(150-256)			(157-310)	(152-317)		
	JH	16.9±3.3cm	18.2±3cm	7.70	0.41	15.9±5.5cm	16.6±4.7cm	4.4	0.14
		(11.94-22.88)	(13.68-23.63)			(6.21-22.99)	(4.86-20.92)		
Isometric force	Trunk flexion	0.56±0.08kg/KG	0.62±0.1kg/KG	10.70	0.66	0.6±0.13kg/KG	0.63±0.15kg/KG	5	0.21
		(0.34-0.67)	(0.49-0.78)			(0.43-0.79)	(0.38-0.84		
	Trunk extension	1±0.22kg/KG	1.26±0.2kg/KG	26.00	1.24*	1.01±0.32kg/KG	1.16±0.38kg/KG	14.9	0.43
		(0.58-1.39)	(0.95-1.7)			(0.61-1.59)	(0.71-1.76)		

Heart rates and energy expenditure were recorded using heart rate monitors (Polar® FT4 und Polar® FT7, Germany), which gave heart rates readings (HR) and estimates of the total energy expenditure during a training session. According to manufacturer information, anthropometric data, HR, and HR_{max} were used to estimate energy expenditure.

Physical exertion was quantified objectively using the mean heart rate during training sessions, averaged across the sessions, and normalized to HR_{max}. In nine out of twelve subjects, HR_{max} occurred during the trampoline sessions, whereas HR_{max} recordings were taken from the treadmill tests for the remaining three subjects. Perceived physical exertion data were collected using a BORG Scale (score 6-20) (5).

Statistical Analysis

Descriptive statistics (mean, SD, range) were calculated for each variable. The mean differences were showed in Box Plots. For each subject, PRE-POST differences were calculated and normalized to the subject's mean. Normal distribution of the differences was assessed using the Shapiro-Wilk test. PRE-POST differences were analyzed using a Wilcoxon Signed Rank-Test. For the group*time interaction, differences between groups pre and post intervention were analyzed using the Mann-Whitney-U-Test. Statistical significance was set at $\alpha=0.05$ and a Bonferroni-Holm correction was applied for multiple tests. This resulted in a corrected α of 0.01 for individual tests. In addition to significance testing, Cohen's d was used as a measure of effect size. Primary clinical endpoints were assessed using the surrogate variables V2, V4, trunk strength, and RSI.

Body composition and perceived physical exertion were considered as secondary clinical endpoints and only analyzed descriptively. The figures are made with Grapher™ 4.0 (Golden Software, Colorado, USA). All statistical procedures were carried out using SPSS 16 (IBM, Germany).

Results

Data from 21 subjects (IG=12, CG=9) were available for analysis (Table 1). No statistically significant between-group differences were found for aerobic capacity, RSI, or trunk strength before intervention (PRE).

We found a nonsignificant PRE-POST increase in V2 (p=0.055) and a statistically significant PRE-POST increase in V4 for the intervention group (p=0.005), however both effect sizes can be considered small (Table 1). V2 and V4 did not change for the control group (p>0.05).

Similarly, small (nonsignificant) PRE-POST effects in the intervention group were found for RSI (p=0.031) and JH (p=0.05) (Table 1). No PRE-POST changes were found for CT in the intervention group (p=0.08). No PRE-POST changes for reactive jumping power variables were found in the control group (p<0.05). The post test difference between the intervention and control groups was not statistically significant for RSI (p=0.039) (Fig. 1).

We found a statistically significant increase and large effect size for trunk extension (p=0.003) and a nonsignificant increase in trunk flexion (p=0.04) with medium effect size. A nonsignificant change in trunk extension (p=0.038) was found for the control group. We found no between-group differences in POST (p>0.05).

No statistically significant group*time interaction effects were for any of the variables (Fig. 2).

The intervention group's mean heart rate during jumping training was 164±13min⁻¹. This corresponds to 83±4% of HR_{max}. Energy expenditure was estimated at 9.7±2.5kcal/min. In general, average heart rates remained constant during the intervention period. Perceived exertion on the BORG scale decreased from 16.6±0.9 in S2 to 13.7±2.5 in S24. The mean perceived exertion level across all sessions was 14.2±2.2.

Discussion

This form of jump training is a fitness trend which aims to improve aerobic capacity and strength, but only few studies have been conducted in this context. The aim of this study was to examine the effects of an eight-week training program with a mini-trampoline on aerobic capacity, reactive jumping power, and trunk strength. No significant group*time interaction effect was found. Significant improvements were found in aerobic capacity for V4 and for trunk strength in the intervention group. Reactive jumping strength showed a nonsignificant increase. The significant changes in the intervention group may be a random effect. Studies have shown that jump training or trampolining improve aerobic capacity and jumping power. However, to date, these effects have not been confirmed for commercially developed fitness training programs.

Significant improvements in running performance with increases in VO_2max after training on a mini-trampoline for several weeks were found in a previous study with comparable training frequency (37), as well as in a study with considerably greater training frequency (five times) and intervention period (eleven weeks) (17). It can be concluded, therefore, that standardized training three times a week for eight weeks with a mini-trampoline can improve aerobic capacity in untrained persons. Following an 11-week intervention in women at intensities between 70-85% HR_{max}, Edin et al. (1990) found a 4.4% improvement in VO_2max, and Sahin et al. (2016) found 7.8% improvements in VO_2max at an intensity of 75% HR_{max} (17, 37). In the present study, subjects trained at 83±4% HR_{max}, which represents a comparable load. According to Scribbans et al. (2016), improvements in aerobic capacity can be achieved across a wide range of training intensities (38).

Studies have shown that the oxidation of pyruvates and fatty acids for energy production is optimized by repetitive, long-lasting exercise due to increased muscle capacity (3, 33). This can be attributed to an increase in mitochondrial proteins, resulting in increased activity of oxidative enzymes (36). Two weeks of high intensity training were able to increase the citrate synthase activity by 43% (41). An eight-week training program on a treadmill, for example, induced not only qualitative, but also quantitative improvements in the mitochondria (44). Following twelve weeks of ergometer training, Konopka et al. (2014) measured an increase in mitochondrial proteins (26). Long-lasting jumping exercise on trampolines appears to induce similar effects. Improved running performance during the incremental tests can therefore be attributed to economizing effects of mini-trampoline training on aerobic glycolysis, which still needs to be investigated on the cellular level. At the same intensity, which was realized using video guidance, perceived exertion decreased. Here, the BORG scale was used to assess perceived exertion, as it is considered to be reliable (28) and correlates closely with physiological variables (HR, lactate, and VO_2 intake) (5, 21, 29).

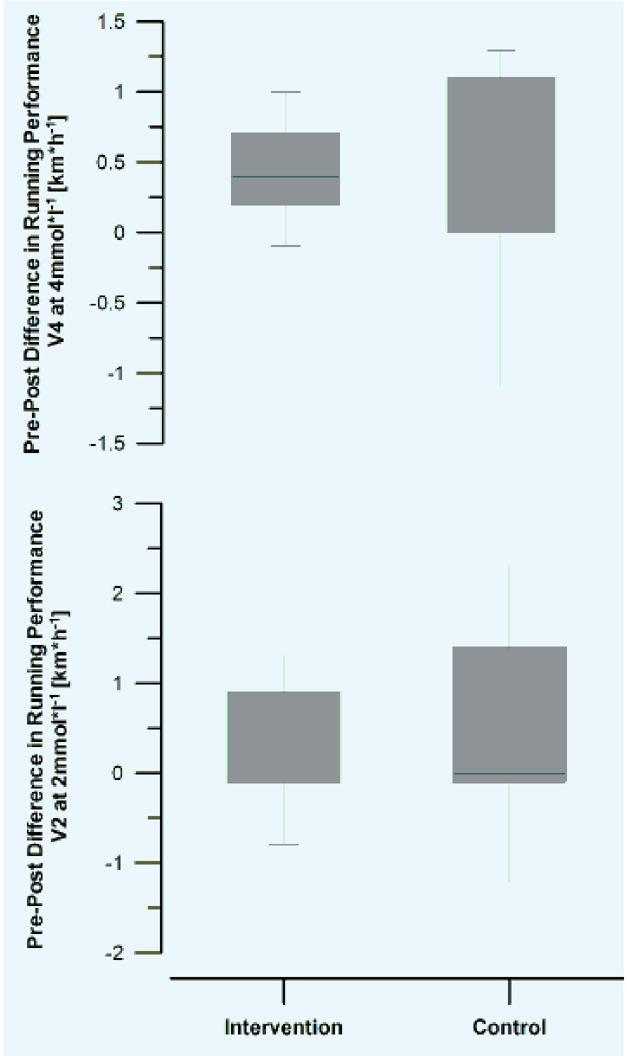

Figure 2

Mean differences and SD of V2 and V4.

The reduced perceived exertion can be explained by an economization of the aerobic metabolism, as well as through improved coordination in jumping technique and sequence of motions.

As already used in other studies, the drop jump provides information about the reactive jump performance (42). In the intervention group, jump performance in the drop jump showed an improvement in RSI (+12.2%). The increase in reactive jump strength is based on improved jump height (+7.7%). Studies using conventional trampolines for training found significant increases in jump height in trained men and children after twelve weeks (25), eight weeks (37), and as early as after four weeks (2) of intervention with three sessions per week, respectively. Trampolining therefore improves jump performance, which is primarily shown by an increase in jump height. No effects on contact time were found in this study. It is possible that the elastic trampoline surface prevents the muscle's extension-contraction cycle (ECC) from being used optimally to improve its contraction speed and strength. Studies have shown that plyometric training of the lower extremities has performance-improving effects (i.e. jumping power, speed) (30). Training interventions on non-rigid surfaces have shown similar results. The jump training implemented here is characterized by quick, short contact times on the elastic surface and requires a quick and powerful hip flexion. With regard to RSI, the present › study found positive though nonsignificant effects on reactive jumping performance. The contact times, however, showed ambiguous effects on muscle function in ECC. Future studies, particularly studies on ECC function, should also examine effects with regard to muscle activation and reflex response.

There is currently little research on changes in trunk strength after running and jumping exercises on a trampoline. Karakollukçu et al. (25) had 20 male gymnasts perform various jumps on mini-trampolines (flips, vertical jumps) three times a week for twelve weeks and found no effects on back strength. Cho et al. (9) found significant improvements in dynamic lumbar stability following a 6-week intervention of stationary running, whereby another study presents contradictory results (39). In our study, subjects in the jumping group were only able to significantly increase maximum isometric strength for trunk extension (+26%). Only a medium effect in trunk flexion increase was found in our data (+10.7%). These subjects carried out jumps similar to aerobic exercises while keeping their trunk bent forward. Muscle activity varies depending on upper body position. Greater trunk flexion increases torque and activity in the back extensor muscles (23). Other authors reported no increase in antagonist co-contraction at submaximal isometric strength measurements of trunk extension (31). Increased EMG activity of the trunk flexors was only seen at greater loads (10, 31). The increased upward movement of the knee toward the sternum (similar to a reverse crunch), particularly during high-impact jumps (i.e. Stomping, Side to Side, 1&1, 2&2), causes increased loading of the trunk flexors. Within the context of classical strength training, this and other similar movement patterns imply high EMG activity in the upper and lower portions of the rectus abdominis and rectus femoris muscles (18).

The small increases within the control group can, in part, be interpreted as habituation effects. Remarkably high increases in trunk extension strength were found for two subjects. While seven subjects showed no changes (on average +0.08kg/KG), two subjects achieved improvements of 0.47 and 0.26kg/KG.

Body composition in the intervention group showed reduced BF (-5.4%). As BF was not a primary endpoint in this study, no significance test was carried out. BF should be examined separately in future training studies. Sahin et al. (37) and Aalizadeh et al. (1) found significant reductions in BF in men and school children after eight and 20 weeks. Other studies found no changes in the body composition of women after eight and eleven weeks of intervention (17, 40). Reducing body weight in the form of body fat is based on a negative energy balance (7). Food consumption was not monitored in any of the available studies, nor was it monitored in the present study. The loss of body fat in the intervention group may be due to a negative energy balance. However, day-to-day variations in fluid intake could have resulted in variable BF (27).

Subjects in the intervention group burned 9.7±2.5kcal/min. The highest energy expenditure in one training session was measured in a male subject at 337kcal. The estimated energy expenditure could not be validated using the manufacturer's documentation. Therefore we must assume a possible under or overestimation of the energy expenditure. A more reliable method would be respiratory gas analysis. McGlone et al. (32), for example, measured 9.45±1.75kcal/min for a training volume of 2x ten minutes. Other studies showed values of 12.4±1.6 kcal/min for men and 9.4±0.9kcal/min for women within a 19-minute workout routine, excluding the warm-up and cool-down periods (6) and 6.9±0.8kcal/min within an approximately 50-minute training session (12). The WHO recommends 75 minutes of strenuous physical activity per week for people between the ages of 18-65 years to help prevent diabetes, cancer, and cardiovascular diseases. Strenuous activity is considered physical activity at levels >6 METs (1 MET= 1 kcal/kg/h) (43). The participants in the intervention group achieved an average of 8.9 METs (6.6-11.1 METs). This shows that regular jump training with a trampoline, using music to control rhythm and movement frequency, can be implemented as an alternative to other exercises to fulfill the WHO recommendations.

The current study only included subjects who were interested and volunteered for the study based on the study description in our call for subjects. Despite a lack of randomization in this study, the initial conditions were largely homogeneous. It was difficult to obtain a larger sample, but future research should strive to recruit samples including more subjects. As subjects carried out these tests for the first time, habituation effects cannot be excluded. Gerberich et al. (22) found that the human body shows different physiological responses (HR, VO_2max) and different perceived exertion depending on the type of test procedure (treadmill running, jogging). In the future, a standardized incremental test on a mini-trampoline may be able to show this specific adaptation. We did not control for changes in daily physical activity (14, 15) or eating and drinking behavior (13), which may have resulted in slight day-to-day fluctuations in body composition. Moreover, TANITA BC-418 MA is presumed to underestimate BF (8, 34).

The data from this study indicate that a standardized eight-week training program on a mini-trampoline may induce not clear effects in aerobic capacity and trunk extension strength. Mini-trampoline exercises induce substantial aerobic intensity and energy expenditure, and can thus be considered an alternative to other types of exercise used for prevention purposes. Further research is necessary to evaluate the potential of mini-trampoline exercise programs for specific target groups.

Conflict of Interest

The authors have no conflict of interest.

References

(1) **AALIZADEH B, MOHAMMADZADEH H, KHAZANI A, DADRAS A.** Effect of a Trampoline Exercise on the Anthropometric Measures and Motor Performance of Adolescent Students. International Journal of Preventive Medicine. 2016; 7: 91. doi:10.4103/2008-7802.186225

(2) **ARABATZI F.** Adaptations in movement performance after plyometric training on mini-trampoline in children. J Sports Med Phys Fitness. 2018; 58: 66-672. doi: 10.23736/S0022-4707.16.06759-1

(3) **BARNARD RJ, EDGERTON VR, PETER JB.** Effect of exercise on skeletal muscle. I. Biochemical and histochemical properties. J Appl Physiol. 1970; 28: 762-766. doi:10.1152/jappl.1970.28.6.762

(4) **BHATTACHARYA A, MCCUTCHEON EP, SHVARTZ E, GREENLEAF JE.** Body acceleration distribution and O2 uptake in humans during running and jumping. J Appl Physiol. 1980; 49: 881-887. doi:10.1152/jappl.1980.49.5.881

(5) **BORG G.** Borg's perceived exertion and pain scales. Human Kinetics Pub Inc: Champaign; 1998.

(6) **BURANDT P, PORCARI JP, CRESS ML, DOBERSTEIN S, FOSTER C.** Putting Mini-Trampolines to the Test. ACE Prosource. 2016: 1–3.

(7) **CATENACCI VA, WYATT HR.** The role of physical activity in producing and maintaining weight loss. Nat Clin Pract Endocrinol Metab. 2007; 3: 518-529. doi:10.1038/ncpendmet0554

(8) **CHEN K-T, CHEN Y-Y, WANG C-W, CHUANG C-L, CHIANG L-M, LAI C-L, LU H-K, DWYER GB, CHAO S-P, SHIH M-K, HSIEH K-C.** Comparison of Standing Posture Bioelectrical Impedance Analysis with DXA for Body Composition in a Large, Healthy Chinese Population. PLoS ONE. 2016; 11: e0160105. doi:10.1371/journal.pone.0160105

(9) **CHO M, JUN I.** The effects of running in place on healthy adults' lumbar stability. J Phys Ther Sci. 2014; 26: 821-824. doi:10.1589/jpts.26.821

(10) **CHOLEWICKI J, PANJABI MM, KHACHATRYAN A.** Stabilizing function of trunk flexor-extensor muscles around a neutral spine posture. Spine. 1997; 22: 2207-2212. doi:10.1097/00007632-199710010-00003

(11) **COHEN J.** Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Taylor and Francis: Hoboken; 2013.

(12) **CUGUSI L, MANCA A, ROMITA G, BERGAMIN M, DI BLASIO A, MERCURO G.** Exercise intensity and energy expenditure during a mini-trampoline rebounding exercise session in overweight women. Sci Sports. 2017; 32: e23-e28. doi:10.1016/j.scispo.2016.06.006

(13) **DEURENBERG P, WESTSTRATE JA, PAYMANS I, VAN DER KOOY K.** Factors affecting bioelectrical impedance measurements in humans. Eur J Clin Nutr. 1988; 42: 1017-1022.

(14) **DIXON CB, ANDREACCI JL.** Effect of resistance exercise on percent body fat using leg-to-leg and segmental bioelectrical impedance analysis in adults. J Strength Cond Res. 2009; 23: 2025-2032. doi:10.1519/JSC.0b013e3181b86735

(15) **DIXON CB, ANDREACCI JL, LEDEZMA C.** Effect of aerobic exercise on percent body fat using leg-to-leg and segmental bioelectrical impedance analysis in adults. Int J Body Compos Res. 2008; 6: 27-34.

(16) **DSSV E. V.** Eckdaten 2017. https: //www.dssv.de/statistik/statistik/ [August 2nd 2017].

(17) **EDIN JB, GERBERICH SG, LEON AS, MCNALLY CARL, SERFASS R, SHAW G, MOY J, CASAL D.** Analysis of the training effects of minitrampoline rebounding on physical fitness, body composition, and blood lipids. J Cardiopulm Rehabil. 1990; 10: 401-408.

(18) **ESCAMILLA RF, BABB E, DEWITT R, JEW P, KELLEHER P, BURNHAM T, BUSCH J, D'ANNA K, MOWBRAY R, IMAMURA RT.** Electromyographic analysis of traditional and nontraditional abdominal exercises: Implications for rehabilitation and training. Phys Ther. 2006; 86: 656-671.

(19) **F&G VERLAGS- UND MARKETING GMBH.** Fitness-Trends Deutschland 2016. F&G 2016. 2016: 22-25.

(20) **F&G VERLAGS- UND MARKETING GMBH.** Fitness-Trends Deutschland 2017. F&G 2016. 2016: 22-26.

(21) **FROELICHER VF, MYERS JN.** Exercise and the heart. 4. ed. Saunders: Philadelphia; 2000.

(22) **GERBERICH SG, LEON AS, MCNALLY C, SERFASS R, EDIN JB.** Analysis of the Acute Physiologic Effects of Minitrampoline Rebounding Exercise. J Cardiopulm Rehabil. 1990; 10: 395-400. doi:10.1097/00008483-199011000-00001

(23) **HUMMER M, KÖSTERS A, MÜLLER E.** Maximales Drehmoment und muskuläre Aktivität in unterschiedlichen Winkelpositionen der Rumpfflexion, Rumpfextension und Rumpfrotation. Sportverletz Sportschaden. 2009; 23: 187-193. doi:10.1055/s-0029-1245036

(24) **JUMPING FITNESS AG WEB SITE.** Jumping Fitness. https://www.jumping.fitness/ [July 24th 2017].

(25) **KARAKOLLUKÇU M, ASLAN CS, PAOLI A, BIANCO A, SAHIN FN.** Effects of mini trampoline exercise on male gymnasts' physiological parameters: A pilot study. J Sports Med Phys Fitness. 2015; 55: 730-734.

(26) **KONOPKA AR, SUER MK, WOLFF CA, HARBER MP.** Markers of human skeletal muscle mitochondrial biogenesis and quality control: Effects of age and aerobic exercise training. J Gerontol A Biol Sci Med Sci. 2014; 69: 371-378. doi:10.1093/gerona/glt107

(27) **KUTAC P.** The effect of intake of water on the final values of body composition parameters in active athletes using two different bioimpedance analyzers. Acta Gymnica. 2014; 44: 107-116. doi:10.5507/ag.2014.011

(28) **LÖLLGEN H.** Das Anstrengungsempfinden (RPE, Borg-Skala). Dtsch Z Sportmed. 2004; 55: 299-300.

(29) **LÖLLGEN H, GRAHAM T, SJOGAARD G.** Muscle metabolites, force, and perceived exertion bicycling at varying pedal rates. Med Sci Sports Exerc. 1980; 12: 345-351. doi:10.1249/00005768-198025000-00008

(30) **MARKOVIC G, MIKULIC P.** Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. Sports Med. 2010; 40: 859-895. doi:10.2165/11318370-000000000-00000

(31) **MCCOOK DT, VICENZINO B, HODGES PW.** Activity of deep abdominal muscles increases during submaximal flexion and extension efforts but antagonist co-contraction remains unchanged. J Electromyogr Kinesiol. 2009; 19: 754-762. doi:10.1016/j.jelekin.2007.11.002

(32) **MCGLONE C, KRAVITZ L, JANOT J.** Rebounding: A Low- Impact Exercise Alternative. ACSM's Health Fit J. 2002; 6: 11-15.

(33) **MORGAN TE, COBB LA, SHORT FA, ROSS R, GUNN DR.** Effects of Long-Term Exercise on Human Muscle Mitochondria. In: Pernow B, Saltin B, eds.: Muscle Metabolism During Exercise. Springer US: Boston, MA; 1971.

(34) **NEOVIUS M, HEMMINGSSON E, FREYSCHUSS B, UDDÉN J.** Bioelectrical impedance underestimates total and truncal fatness in abdominally obese women. Obesity (Silver Spring). 2006; 14: 1731-1738. doi:10.1038/oby.2006.199

(35) **NITZSCHE N, STUTZIG N, WALTHER A, SIEBERT T.** Effects of Plyometric Training on Rock'n'Roll Performance. International Journal of Kinesiology and Sports Science. 2015; 3: 8-15.

(36) **POORTMANS JR, ED.** Principles of exercise biochemistry: 19 tables. 3., rev. ed. Karger: Basel; 2004.

(37) **SAHIN G, DEMIR E, AYDIN H.** Does Mini-Trampoline Training More Effective than Running on Body Weight, Body Fat, VO2max and Vertical Jump in Young Men? International Journal of Sports Science. 2016; 6: 1-5.

(38) **SCRIBBANS TD, VECSEY S, HANKINSON PB, FOSTER WS, GURD BJ.** The Effect of Training Intensity on VO2max in Young Healthy Adults: A Meta-Regression and Meta-Analysis. Int J Exerc Sci. 2016; 9: 230-247.

(39) **SHARROCK C, CROPPER J, MOSTAD J, JOHNSON M, MALONE T.** A pilot study of core stability and athletic performance: Is there a relationship? Int J Sports Phys Ther. 2011; 6: 63-74.

(40) **TOMASSONI TL, BLANCHARD MS, GOLDFARB AH.** Effects of a Rebound Exercise Training Program on Aerobic Capacity and Body Composition. Phys Sportsmed. 1985; 13: 110-115. doi:10.1080/00913847.1985.11708928

(41) **VINCENT G, LAMON S, GANT N, VINCENT PJ, MACDONALD JR, MARKWORTH JF, EDGE JA, HICKEY AJR.** Changes in mitochondrial function and mitochondria associated protein expression in response to 2-weeks of high intensity interval training. Front Phys. 2015; 6: 51. doi:10.3389/fphys.2015.00051

(42) **WIRTH K, SANDER A, KEINER M, SCHMIDTBLEICHER D.** Leistungsfähigkeit im Dehnungs-Verkürzungs-Zyklus sportlich aktiver und inaktiver Kinder und Jugendlicher. Dtsch Z Sportmed. 2011; 62: 345-350.

(43) **WORLD HEALTH ORGANIZATION.** Global recommendations on physical activity for health. WHO: Geneva; 2010.

(44) **ZOLADZ JA, KOZIEL A, WOYDA-PLOSZCZYCA A, CELICHOWSKI J, JARMUSZKIEWICZ W.** Endurance training increases the efficiency of rat skeletal muscle mitochondria. Pflügers Arch. 2016; 468: 1709-1724. doi:10.1007/s00424-016-1867-9