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The effect of high intensity, short duration trampolining on human physiology across an 8-week intervention

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ABSTRACT
The aim of this study was to investigate whether a high intensity, short duration protocol on a trampoline would significantly alter physiological markers across an 8-week intervention. A controlled trial design was used. Twenty-three healthy adults were recruited for the study. The intervention group completed 100 bounces on a trampoline, at the maximum possible intensity, 4 times per week for 8 weeks. The control group maintained their current level of exercise across the 8 weeks. Body fat, muscle mass, blood pressure, resting heart rate, blood oxygenation, blood pressure, total blood cholesterol (fasted), $\dot{V}O_2max$ *and vertical jump were assessed at Week 0,4 and 8 for both groups. A one way repeated measures MANOVA was used for both the intervention and control group. A difference was found between the means of the variables for the intervention group, but not for the control group. Analysis was then continued, for the intervention group, to discern where the change had occurred. A series of one way repeated measures ANOVAs found a significant change had occurred for blood cholesterol, relative* $\dot{V}O_2$*, vertical jump, total bounce height, time to completion and caloric expenditure. The results of this study indicate that using a high intensity, short duration protocol on a trampoline may improve physiological markers with as little as eight minutes of exercise per week. Therefore, this could provide a novel and time efficient method of exercise.*

1. Introduction

Engaging in regular exercise causes adaptions to many physiological markers which in turn may provide various health benefits including; increased muscle mass (Rogers & Evans, 1993), increased bone density (Marques et al., 2012), improved cardiovascular function (Berthouze et al., 1995), mental health benefits (Lawlor & Hopker, 2001) and a decreased mortality risk (Nocon et al., 2008). Despite this, lack of regular exercise is the fourth greatest risk factor for non-communicable diseases, which is estimated to cause 3.2-5 million deaths per year (McIntyre, 2015). One of the most common barriers to engaging in regular exercise is a lack of time (Schutzer & Graves, 2004). The current guidelines for physical activity recommend either 2.5 hours of moderate or 1.25 hours of vigorous intensity exercise per week (McIntyre, 2015). For a person with limited free time this may be an unrealistic goal.

Low availability of free time is commonly listed as a major contributing factor to lack of participation in exercise (Greaney et al., 2009). Therefore, if the duration of exercise can be reduced, this may make participating in regular exercise more attractive. In recent years the popularity of high intensity interval training (HIIT) has increased dramatically. The premise behind HIIT training is to use a high work intensity across multiple, short duration bouts to reduce exercise time. Meta-analyses investigating HIIT vs steady state exercise found either superior or matched improvements to cardiovascular function (Ramos et al., 2015) and body composition (Wewege et al., 2017), despite steady state exercise being performed for significantly longer periods of time. This difference in required time makes HIIT an attractive exercise modality to those with limited time availability.

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Jumping on a non-compliant surface as an exercise regime (also known as plyometrics) has been investigated extensively. Plyometrics have been shown to provide significant benefit to; leg muscular power output (de Villarreal et al., 2009; Stojanović et al., 2017) and bone density (Zhao et al., 2014). Comparisons between the training results of jumping on a compliant surface (such as a trampoline) and a non-compliant surface (such as the ground) may not be appropriate. This is because it has been shown that the jumping action significantly differs between a compliant and non-compliant surface (Crowther et al., 2007). Therefore, conclusions from studies conducted on non-compliant surfaces may not be applicable to trampolining.

Mini-trampolines (also known as rebounders) are the most popular, compliant-surface, modality used in a research setting. Exercise using rebounders has been shown to improve; stability (Arabatzi, 2018), vertical jump (Şahin et al., 2016), anthropometric measures (Cugusi et al., 2016), cardiovascular function (Şahin et al., 2016) and insulin resistance (Nuhu & Maharaj, 2017). At the surface level, the bouncing action of rebounders and trampolines may appear similar, but there are some fundamental differences. On a rebounder, the bouncing action is often focused on a downward push into the mat, which limits the upwards propulsion (McGlone et al., 2002). Whereas, the bouncing action on a trampoline is solely focused on upwards propulsion. The bouncing action on a rebounder can then be further characterised as either a "bounce" or a "jog". With the different characterisations producing significantly different physiological responses (Gerberich et al., 1990). How these differences between the bouncing action on a trampoline and rebounder affects the results of a training regime haven't been investigated at this time. Therefore, the conclusions from studies conducted on rebounders may, also, not be applicable to trampolining.

Research directly investigating exercise on trampolines has shown significant benefit to; anthropometric measures, jump height, balance and leg power (Aalizadeh et al., 2016). Some papers have also investigated rate of energy expenditure while bouncing on a trampoline (Alexander et al., 2020; Clement et al., 2020; Draper et al., 2020), which required measurement of oxygen consumption during exercise. No papers, at this point, have directly investigated the efficacy of using a trampoline to improve cardiovascular fitness.

For a protocol to be considered HIIT, multiple intervals must be used. Due to the appeal of low time commitment, a single, max effort, protocol was devised. This experiment uses a single, high intensity, short duration (HISD) protocol. To the best of the author's knowledge a HISD protocol hasn't been used before. Therefore, the aim of this study was to investigate whether HISD exercise, on a trampoline, would significantly improve physiological markers across an 8-week intervention.

2. Methods

2.1. Participants

The study was completed in three separate blocks from September 2018-November 2018, February 2019-June 2019 and June 2020-August 2020. Twenty-five participants were recruited for the intervention group (8 were removed due to non-adherence, two were removed due to injury/sickness not related to the study, one was removed due to injury related to the study). Ten participants were recruited for the control group (One was removed due to non-adherence).

The analysis group consisted of 23 healthy adults (8 Male, 15 Female) (14 intervention group, 9 control group). Participants ranged from 19-60 years of age, with a mean age of 29±12 years. Means of the anthropomorphic measures for males and females were respectively; height (180 ± 3cm) (164 ± 5cm), mass (93 ± 18kg) (71 ± 15kg) and BMI (29 ± 7) (27 ± 6). The participants had a range of prior trampolining experience, ranging from having no prior trampolining experience to having four years of experience competing in gymnastic trampolining. None of the participants had regularly bounced on a trampoline in the prior five years to beginning the study. Exclusion criteria were health risks that contraindicate exercise testing (American College of Sport Medicine, 2013), diseases that are associated with loss of balance, as well as the presence of infections, injuries or an existing drug treatment that could potentially limit physical performance. Participants who passed the screening were given detailed information about the study's aim and protocol and gave written consent before participation. This study was approved by the ethics committee of the University of Canterbury and was registered with the Australia, New Zealand Clinical Trials Registry (26/11/2019), registration number: ACTRN12619001646134. All procedures were performed in accordance with the relevant guidelines and regulations.

2.2. Procedure

2.2.1. Testing

Participants were required to visit the University of Canterbury Physiology Laboratories at Week 0, Week 4 and Week 8 of the intervention. The full testing session took approximately an hour each visit. All testing sessions were completed in the morning and participants were instructed to fast prior to the session (no water or food since the previous evening).

Body mass was obtained using a bio-impedance scale (Inbody 230, Inbody, Seoul, Korea). Body-fat and muscle mass were obtained using the same machine by method of bioelectrical impedance analysis (Lukaski et al., 1985). Next, blood pressure was assessed using an automated blood pressure cuff (5200-103Z, Welch Allyn, New York, USA), which measured the participants resting heart rate, blood oxygenation and systolic/diastolic blood pressure. Total blood cholesterol (fasted) was then assessed using lancet blood sampling (BK6-10M, Benecheck, New Taipei City, Taiwan).

At this point the participants were encouraged to eat and drink if they desired. Next, each participant underwent a $\dot{V}O_2$max test using an athlete led protocol (Hamlin et al., 2012) using a breath by breath analyser (K5, COSMED, Rome, Italy) to assess $\dot{V}O_2$max. Following the $\dot{V}O_2$max, the participant was instructed to rest until they felt fully recovered (a 5-minute minimum was utilised). Finally, anaerobic power was assessed using vertical jump height (Yardstick, Swift Performance Equipment, NSW, Australia). The participant was instructed to stand beneath the yardstick, then to extend their arm up and swipe the highest marker they could reach without their heels coming off the floor.

This value was considered their reach. For each jump, their reach was subtracted from total jump height. For their jumps, no run up was allowed. Each participant was allowed three attempts. A one-minute rest was used between attempts. Their highest score was recorded.

Finally, the average amount of hours the participant spent exercising, weekly, outside of the intervention, was recorded. Participants were instructed to maintain their current level of exercise outside of the intervention and were excluded if the amount changed by more than an hour per week.

2.2.2. Intervention

For the duration of the 8 weeks, the intervention group were required to come into the laboratory 4 times per week to bounce on the designated trampoline (O77, Springfree, Christchurch, New Zealand). Participants were excluded if they completed less than an average of 4 sessions per week. Each session consisted of the participants first completing a 10-bounce warm-up at a self-directed, moderate intensity. The participant then completing a further 100 bounces at the maximum intensity (height) they were capable of. For each session; time to completion, total bounce height (the cumulative height of the 100 bounces) and caloric expenditure (during the 100 bounces) were recorded using the TGOMA software on the trampoline (TGOMA, Springfree, Christchurch, New Zealand).

The control group completed no bouncing sessions during the 8 weeks and were instructed to maintain their current level of exercise.

2.3. Statistical Analysis

Statistical analysis was performed using SPSS Statistics for Windows (Version 25.0, IBM Corp, Armonk, NY, USA). Datasets were first assessed for normality using a Shapiro-Wilks test. All variables were found to follow a normal distribution, therefore multivariate normality was assumed. Two, separate, one way repeated measures MANOVAs were used to assess whether significant differences existed between the means, for each of the variables, for both the intervention and control group ($p \leq 0.05$). Significant difference was found between the variables for the intervention group, but not the control group. Due to finding no significant differences analysis was not continued for the control group.

For the intervention group, a series of repeated measures ANOVAs were used to identify the degree of significance between the time points for each of the variables. The data set for vertical jump failed Mauchly's Test of Sphericity ($p = 0.006$), therefore a repeated measures ANOVA with a Greenhouse-Geisser correction was used for this dataset. Partial eta squared was used to interpret the effect size for all variables. Post hoc tests using the Bonferroni correction were then used to identify when these changes occurred for each of the variables.

Finally, independent samples t-tests were used to compare means, between the intervention and control group, for vertical jump and relative $\dot{V}O_2max$, for each of the time points. To investigate whether either group began with a significantly higher base fitness.

3. Results

Two, one way repeated measures MANOVAs were used to assess whether significant differences existed between the means for mass, muscle mass, fat mass, blood pressure, blood cholesterol, relative $\dot{V}O_2max$ and vertical jump for both the intervention and control group. A difference was found between time points for the intervention group ($F_{12,18}= 2.767$, $p = 0.038$), but not for the control group ($F_{14,16}= 0.654$, $p = 0.794$). Descriptive statistics for the control and intervention can be seen in Table 1.

A series of one-way repeated measures ANOVAs were then used to identify which of the measured variables had changed for the intervention group. A difference was found for blood cholesterol ($F_{2,26}= 7.358$, $p = 0.003$, $\eta_p^2 = 0.4$), relative $\dot{V}O_2max$ ($F_{2,26}= 4.185$, $p = 0.027$, $\eta_p^2 = 0.2$), vertical jump ($F_{1.267,16.468}= 10.547$, $p = 0.003$, $\eta_p^2 = 0.4$), total bounce height ($F_{2,26}= 4.956$, $p = 0.015$, $\eta_p^2 = 0.3$), time to completion ($F_{2,26}= 20.779$, $p < 0.0005$, $\eta_p^2 = 0.6$) and caloric expenditure ($F_{2,26}= 4.956$, $p = 0.015$, $\eta_p^2 = 0.3$).

Table 1: Means ± SD of the variables for the control and intervention groups.

	Control Pre	Control Post	Intervention Pre	Intervention Post
Mass (kg)	79 ± 18.2	79.4 ± 19.3	78.6 ± 20.0	78.6 ± 20.1
Muscle Mass (kg)	31 ± 7.6	31.6 ± 7.7	30.5 ± 8.0	30.5 ± 8.0
Fat Mass (kg)	24 ± 13.8	23.5 ± 12.7	24.1 ± 12.8	24.3 ± 12.7
Systolic Blood Pressure (mmHg)	123 ± 13	119 ± 10	119 ± 14	114 ± 14
Diastolic Blood Pressure (mmHg)	76 ± 9	74 ± 6	74 ± 7	73 ± 8
Blood Cholesterol (mmol/L)	4.5 ± 0.5	5.5 ± 1.5	5.0 ± 1.3	5.7 ± 1.7
Relative $\dot{V}O_2$ (mL/min/kg)	44 ± 8.5	40.8 ± 7.2	40.2 ± 8.4	42.6 ± 9.9
Vertical Jump (cm)	41 ± 9	43 ±10	32 ± 9	36 ± 9*

Note: * indicate significant change occurred within the intervention group

Table 2: Means ± SD of the variables for the intervention group.

	Week 0	Week 4	Week 8
Mass (kg)	78.6 ± 20.0	78.7 ± 20.9	78.6 ± 20.1
Muscle Mass (kg)	30.5 ± 8.0	30.2 ± 8.8	30.5 ± 8.0
Fat Mass (kg)	24.1 ± 12.8	25.1 ± 14.1	24.3 ± 12.7
Systolic Blood Pressure (mmHg)	119 ± 14	119± 15	114 ± 14
Diastolic Blood Pressure (mmHg)	74 ± 7	75 ± 9	73 ± 8
Blood Cholesterol (mmol/L)	5.0 ± 1.3	6.2 ± 1.4*	5.7 ± 1.7
Relative $\dot{V}O_2$ (mL/min/kg)	40.2 ± 8.4	44.1 ± 7.4*	42.6 ± 9.9
Vertical Jump (cm)	32 ± 9	34 ± 9	36 ± 9*
Total Jump Height (m)	46 ± 20.7	61.6 ± 24.7*	69 ± 25.7
Time to completion (s)	110 ± 9	116 ± 10*	119 ± 11*
Caloric Expenditure (kcal)	34 ± 27	45 ± 43*	50 ± 48

Note: * indicates significant change occurred within the intervention group

Post hoc tests found that blood cholesterol increased Week 0-4 (p = 0.001). No change occurred Week 4-8 (p = 0.403). Overall, no change occurred Week 0-8 (p = 0.255).

Relative $\dot{V}O_2$max increased Week 0-4 (p = 0.04). No change occurred Week 4-8 (p = 0.481). Overall, no change occurred Week 0-8 (p = 0.502).

For vertical jump, no change occurred Week 0-4 (p = 0.213). An increase occurred Week 4-8 (p = 0.002). Overall, an increase occurred Week 0-8 (p = 0.005).

Total bounce height increased Week 0-4 (p = 0.04). No change occurred Week 4-8 (p = 0.114). Overall, an increase occurred Week 0-8 (p = 0.04).

For time to completion no change occurred Week 0-4 (p = 0.035). An increase occurred Week 4-8 (p = 0.001). Overall, an increase occurred Week 0-8 (p = 0.035).

Caloric expenditure increased Week 0-4 (p = 0.04). No change occurred Week 4-8 (p = 0.114). Overall, an increase occurred Week 0-8 (p = 0.04). Descriptive statistics for the variables of the intervention group can be seen in Table 2.

Finally, independent samples t-tests were used to compare the means for vertical jump and relative $\dot{V}O_2$max between the intervention and control group for each of the time points. This was to confirm that both the intervention and control group began with a similar baseline fitness. No differences were found for either variable for any of the time points ($p < 0.05$).

4. Discussion

The aim of the study was to investigate whether a HISD protocol on a trampoline would cause significant change to physiological markers of the participants. Omnibus tests indicated significant change had occurred for the intervention group, but not for the control group (see Table 1). Further analysis for the intervention group found that the change had occurred for blood cholesterol, relative $\dot{V}O_2$max, vertical jump, total bounce height, time to completion and caloric expenditure.

No significant change occurred for mass, muscle mass, fat mass or blood pressure for either group (see Table 1). This suggests that this intervention had little to no effect on these attributes, for the considered time frame, and therefore is likely not a viable modality for affecting change related to these markers.

The intervention group did see an increase to the total blood cholesterol Week 0-4. Exercise may affect blood cholesterol by increasing the concentration of high-density lipoprotein (HDL) (Tambalis et al., 2009). Increasing the concentration of HDL relative to low-density lipoprotein (LDL) is considered to be a positive change (Hooper et al., 2001). It is also well known that high total blood cholesterol is a risk factor for heart disease (Kannel et al., 1971). The measuring equipment used in this study was unable to discern between HDL and LDL concentration. Therefore, it cannot be concluded whether this change in total blood cholesterol was positive or negative. Future research, using more sensitive testing equipment, is necessary to ascertain the nature of this change.

This research found that relative $\dot{V}O_2$max increased Week 0-4, then no change occurred Week 4-8 for the intervention group. With overall, (Week 0-8) no change occurring. The authors' hypothesis for this phenomenon is that the participants tried significantly harder during the $\dot{V}O_2$max in the Week 0 and Week 4 testing days. This theory is supported by two different results. First, the control group (see Table 1) saw a negative change in their $\dot{V}O_2$max. The control groups Week 0 $\dot{V}O_2$max was 44 ± 8.5 which then decreased to 40.9 ± 9.4 in Week 4 and decreased again to 40.8 ± 7.2 in Week 8. Whereas, the intervention group improved from their Week 0 result. Second, manual inspection of the graphs of output of the $\dot{V}O_2$max tests, showed a distinct lack of plateauing of the gradient of the graph for five of the participants (3 intervention, 2 control). This indicates that these participants did not reach their $\dot{V}O_2$max during the final testing day (Week 8). The protocol used in this study was athlete-led. With the participant instructed to cease the test at the point where they felt they could no longer continue. Max effort cardiovascular tests are inherently difficult. Requiring pushing to a level of fatigue that most participants find unpleasant. It is likely that participants were unwilling to exert themselves as strongly in the latter testing days, therefore lowering their results. Pushing to extreme fatigue is likely to injure the participant. Further research should consider this phenomenon and be prepared to control for it.

These results indicate that cardiovascular fitness may be improved above the baseline level with a low exercise dosage on a trampoline. The current guidelines for physical activity recommend either 2.5 hours of moderate or 1.25 hours of vigorous exercise per week to maintain good health (McIntyre, 2015). The protocol used in this study equated to approximately 6-8 minutes of vigorous exercise per week. This means that just 10% of the recommended dosage caused an improvement to the participant's fitness. This indicates that a HISD protocol on a trampoline could be a relevant exercise modality for those with limited time availability for exercise. Further research with a larger sample size is necessary to further validate this finding.

A draw-back of traditional HIIT training is it requires an intensive warm-up protocol to allow maximum effort exertion, as high exertion from a resting state dramatically increases the chance of injury (Shellock & Prentice, 1985). Warm ups associated with HIIT are often similar in length to the exercise protocol (10 minutes warming up vs 16 minutes of HIIT) (Foster et al., 2015). Traditional warm up times for vigorous exercise can be anywhere from 5-30 minutes long (McGowan et al., 2015). For this study the protocol utilised a warm-up consisting of 10 bounces on the trampoline, at a moderate intensity, selected by the participant. This took approximately 10 seconds to complete and, therefore, did not add a significant amount of time to the protocol. This suggests that a HISD exercise protocol on a trampoline may be an even more time efficient exercise modality than traditional forms of HIIT. Of note is that one participant dropped out this study due to an injury sustained during the study, so further investigation is necessary to validate the use of such a short duration warm up.

The participant's vertical jump also improved significantly. Two papers were found investigating trampolining's effect on vertical jump. Both reported trampolining significantly improved vertical jump (Atilgan, 2013; Ross & Hudson, 1997). The authors hypothesised that the increased vertical jump was because of improvement to the participant's jumping technique, specifically to their co-ordination (the timing of the contraction of the participant's muscles during their jump). This study has found a similar result. This suggests that trampolining is a viable modality for improving the technique of a vertical jump. This may also lead to improvement in the user's vertical jump height.

Of note is that the participant's trampolining ability increased dramatically during the intervention. Improvement to trampolining ability can be measured by an increase to the participant's total bounce height. Improving total bounce height will also increase time spent in the air and caloric expenditure. The average Week 0 total bounce height was 46 meters which, by Week 8, increased to 69 meters. This meant the amount of work done during each session increased dramatically across the intervention. Exercise has a dose-response relationship (Iwasaki et al., 2003). This means that as work increases, the response to exercise increases proportionally. Across the intervention, the average total bounce height of the participants increased by 50%. Therefore, their work output became significantly higher towards the end of the intervention. This indicates that the participants experience a significant learning effect across the intervention. Such a dramatic improvement in ability is unlikely to occur during a study using more traditional exercise modalities (such as running or biking). This is because the participant is likely to have a higher previous experience level with the more common exercise modalities. By increasing the length of the intervention, the learning effect of a novel exercise will be minimized. Further research should consider using longer intervention lengths to mitigate how the learning effect affects outcomes on a trampoline.

Conflict of Interest

The authors declare no conflict of interests.

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