Energy Matching of a High Intensity Exercise Protocol with a Low Intensity Exercise Protocol in Young People

Lindsay Bottoms[1]*, Neil Howlett[1], Angel Chater[2], Andy Jones[3], Julia Jones[1], Solange Wyatt[1], Silvana E. Mengoni[1], Shivani Sharma[1], Karen Irvine[1], Daksha Trivedi[1], and David Wellsted[1]

[1] University of Hertfordshire, Hatfield, UK; n.howlett@herts.ac.uk (N.H.); j.jones26@herts.ac.uk (J.J.); s.wyatt5@herts.ac.uk (S.W); S.mengoni@herts.ac.uk (S.M.); S.3.sharma@herts.ac.uk (S.S.); k.irvine2@herts.ac.uk (K.I.); d.trivedi@herts.ac.uk (D.T.) and d.m.wellsted@herts.ac.uk (D.W.).
[2] University of Bedfordshire, Luton, UK; angel.chater@beds.ac.uk
[3] University of East Anglia, Norwich, UK; a.p.jones@uea.ac.uk
* Correspondence: l.bottoms@herts.ac.uk; Tel.: +44-1707-285685; ORCID: https://orcid.org/0000-0003-4632-3764

Abbreviations:

EE – energy expenditure

HIIE- high intensity interval exercise

HR – heart rate

LIE – low intensity exercise

METs – metabolic equivalents

READY - randomised controlled trial of energetic activity for depression in young people

RPE – ratings of perceived exertion

VCO_2 – volume of carbon dioxide

VO_2 – volume of oxygen

1. Introduction

Recent research suggests that exercise is a beneficial adjunct therapy for many health conditions [1]. For clinicians to be able to prescribe exercise to patients, more information is required around the intensity and duration of exercise and more specifically, guidelines need to be developed to ensure a consistent approach to patient care. When designing exercise intervention trials to explore the effects of different intensities, the same volume of exercise needs to be employed between experimental groups to ensure that any differences in responses result from differences in intensity and not energy expenditure (EE). This is because metabolic and peripheral adaptations such as mitochondrial and capillary density respond to the volume of exercise training rather than the intensity [2].

The current study was undertaken as pilot work for a randomised controlled trial of energetic activity for depression in young people (13-17 years) (the READY trial: https://www.journalslibrary.nihr.ac.uk/programmes/hta/177810/#/). Prior to undertaking the READY trial, the protocol for the exercise intervention was pilot tested. To ensure fair comparison between the high and low intensity group exercise protocols they needed to be energy matched. The high intensity exercise protocol was adapted from Taylor et al. [3] which included activities such as boxing and football drills. These had been previously demonstrated to be acceptable, enjoyable and engaging amongst young people (14.0 ±0.3 years). The duration of the high intensity exercise intervention previously utilised by Taylor et al. [3] was 9 minutes, which was achievable by the participants and therefore the present pilot tested used this duration for one of the activities; boxing. The low intensity exercise intervention selected for the study was indoor walking football. At the time of writing this there was no research measuring exercise intensity or EE in indoor walking football in young people. However, as walking at comfortable speeds is categorised as low intensity [4], the research team chose it as an appropriate activity. Walking per se would have brought an extraneous variable as it would have had to be completed outside and hence may affect depressive symptoms differently to indoor exercise. Nevertheless, for the purpose of this pilot testing, simulated walking football was compared with walking to ensure there were no substantial differences in intensity.

The pilot testing aimed to match the EE in the low and high intensity exercise interventions using indirect calorimetry. This involved calculating the average EE per minute during the low intensity protocol and determining the exercise duration to match the EE during the 9-minute-high intensity protocol.

2. Methods

Twenty-four participants (15 boys) volunteered to take part in this study (see Table 1 for characteristics). They completed a health screen questionnaire prior to participating and were found to be healthy and injury free. They received a £10 Amazon voucher for taking part. Recruitment occurred via advertisement at the University

of Hertfordshire which targeted at staff with adolescent children. Ethical approval was obtained from the University of Hertfordshire ethics committee (Reference number: LMS/SF/UH/03759) and the study followed the principles outlined in the Declaration of Helsinki. Informed consent was obtained from both the parent and the adolescent, and participants were free to withdraw at any point prior to the completion of data collection.

Table 1 near here

The participants attended the sports science laboratory in sports clothing on one occasion after fasting for at least 2 hours. The session lasted approximately one hour where they first undertook walking on a treadmill at a comfortable walking speed for 5 minutes to represent low intensity exercise. Following this, they completed the low intensity exercise (LIE) protocol, simulated walking football, for 10 minutes, and then rested until their heart rate (HR) had returned to baseline. Finally, they completed the high intensity interval exercise (HIIE) protocol, which was boxing using focus pads lasting 9 minutes.

2.1 Protocol:

On arrival to the laboratory, stature (m) was measured on a stadiometer (Seca 217 Stadiometer, Seca, Hamburg, Germany) after holding a maximal inhalation, with participants standing without shoes, heels and back touching the stadiometer, head in the Frankfort horizontal plane. Body mass (kg) (Seca 799, Seca, UK) was measured on a flat, uncarpeted surface. Following this, the participant was shown how to use the treadmill (H/P/COSMOS Sports & Medical, Nussdorf-Traunstein: Germany) correctly, ensuring they were able to comfortably walk on it. A comfortable walking speed was determined for each participant depending on their height (<165cm they walked at 4 $km.hr^{-1}$, >165cm they walked at 4.5 $km.hr^{-1}$).

A HR monitor strap (Polar H10, Polar Electro Oy, Finland) was positioned around the participant's chest and baseline HR was recorded after 5 minutes of seated rest. The participant then had a facemask (V Mask, Hand Rudolph, USA) placed over their nose and mouth and secured in place with a hairnet (Hans Rudolph, USA). The portable gas analyser (Metamax 3B, Cortex Biophysik, Leipzig, Germany) was positioned like a rucksack over their shoulders. The weight of the gas analyser was ~1.3 kg. The participant was asked to walk for 5 minutes at a comfortable walking speed on the treadmill. During the last minute of walking, the participant provided a rating of perceived exertion (RPE; 6-20 scale) for how hard they found the intensity of exercise. On completion, they were asked to undertake the simulated walking football task. This took place outside of the laboratory. They walked between 2 cones placed 14m apart. Every 4th repetition they dribbled the football and then kicked it at 70-degree angle at the end of the 14m. They continued walking between cones. This was repeated until 10 minutes was completed. During the last minute of the simulated walking football RPE was recorded. Participants then sat approximately for 5 minutes until their breathing and HR had returned to resting levels.

They completed the HIIE protocol. This included 45s of high intensity boxing exercise followed by 90s of rest. This was repeated four times (to provide a total duration of nine minutes); see Table 2 for exercise details. The facemask and gas analyser were worn throughout the whole protocol and an RPE rating was given immediately post the last high intensity effort.

Table 2 near here

2.2 Gas Analysis:

Prior to data collection, the gas analyser was calibrated using a three-point calibration procedure as per manufacturer's instructions. First, barometric pressure was analysed followed by calibration of the analyser against a mixture of gases with known concentrations (5% CO_2, 17% O_2). Finally, the volume transducer in the analyser was calibrated with a 3-litre calibration syringe (Series 5530, Hans Rudolph, USA).

Variables recorded breath by breath from the gas analyser during exercise included oxygen consumption ($\dot{V}O_2$; $l.min^{-1}$), carbon dioxide production ($\dot{V}CO_2$; $l.min^{-1}$) and HR (bpm) every breath. Consequently, indirect

calorimetry was used to calculate EE (kcal.min^{-1}) using stoichiometric equations specifically developed for exercise at intensities between 40-50% $\dot{V}O_{2peak}$ (low intensity) and 50-75% $\dot{V}O_{2peak}$ (moderate to high intensity) as shown below [5].

Equation 1:

Energy Expenditure for low intensity exercise (kcal.min^{-1}) =$[(0.575 \cdot VCO2) - (4.435 \cdot VO2)]$

Equation 2:

Energy Expenditure for high intensity exercise (kcal.min^{-1}) =$[(0.550 \cdot VCO2) - (4.471 \cdot VO2)]$

2.3 Data analysis:

Total EE was calculated from the expired gases of the HIIE protocol using Equation 1 above for high intensity exercise intervals and Equation 2 for the rest intervals. Then an average EE for one minute for the LIE was calculated using Equation 2. From this, the duration needed for the LIE to match the HIE was calculated using Equation 3.

Equation 3:

Total duration in minutes to energy match = Total HIIE EE / LIE average EE per minute

To determine the Metabolic equivalents (METs) of the exercise, the estimated number of calories was calculated for one hour and then divided by the participant's weight in kg. This was then divided by the estimated resting metabolic rate of either adolescent males (1.28 kcal/kg x h) or females (1.11 kcal/kg x h). This was adapted from Melzer et al. [4]. Microsoft Excel was used to determine means and SD.

3. Results

The mean ±SD calculated time for LIE to energy match the HIIE protocol for all participants was 11.9 ±1.9 min. As can be seen in Table 3, exercise intensity was similar between treadmill walking (54 ±8% HR_{max}) and LIE (59 ±8% HR_{max}) whereas HIIE produced a higher HR of 82 ±7%HR_{max}. Table 3 also displays the RPE scores for each exercise protocol, demonstrating treadmill walking to be 8 ± 2 (between extremely light and very light), LIE was 9 ± 2 (very light) and HIIE was 16 ± 2 (between hard and very hard). Total EEs for the duration of each exercise protocol (treadmill 5 minutes, LIE 10 minutes and HIIE 9 minutes) are presented in Table 3, along with the average EE per minute and as METS.

Table 3 near here

4. Discussion

This pilot testing was undertaken to determine the duration of low intensity exercise, in this case walking football, needed to energy match a high intensity exercise protocol such as boxing in young people. Findings suggest that, approximately 12 minutes of LIE is needed for 9 minutes of HIIE. It must be noted that the HIIE is equivalent to 3 minutes of actual exercise along with 6 minutes of rest whereas the LIE is continuous exercise for 12 minutes. When designing exercise interventions using similar intensities (~80%HR_{max} for HIIE and ~55%HR_{max} for LIE), the LIE duration therefore needs to be 133% that of the total HIIE protocol duration.

When calculating METs for this study, the LIE protocol was 3.6 METs and the HIIE was 5.4 METs which classifies them as both moderate physical activities. However, the HR as a percentage of maximum shows distinct differences between the exercise protocols. High intensity interval training is thought to be ≥80% HR_{max} [2] and the present study demonstrated a HR_{max} of 82 ±7%. In addition, the participants perceived the LIE to be 'very

light' whereas they rated the HIIE between 'hard' and 'very hard', emphasising the differences in intensity between protocols. It is important that when implementing a HIIE protocol similar to the current study, participants need to be constantly motivated to exercise as hard as they can to ensure they are exercising at a sufficiently high intensity.

The treadmill protocol was included in this study to represent low intensity exercise by walking at a comfortable speed and comparing it to the simulated walking football protocol (LIE). The $\%HR_{max}$ between conditions were similar with the treadmill walking eliciting 54 ± 8% and the LIE 59 ±8%. As both are lower than 60% HR_{max}, they can be classified as low intensity exercise. Physiological variables were similar between the treadmill walking and the LIE, as well as the perceived exertion being between extremely light and very light suggesting that the LIE protocol represents a true low intensity exercise.

Exercise interventions for young people with depression are poorly defined, making it difficult for multi-disciplinary professionals to prescribe them. In preparation for a randomised controlled feasibility trial, this study has identified the level of LIE that would map on to HIIE to provide evidence on their respective impact on young people with clinically significant depressive symptoms. There is limited research comparing energy expenditure in this age group for high and low intensity exercise, therefore the current study adds to the potential methodology for energy matching exercise trials in adolescents. Nevertheless, there are some limitations to consider. Firstly, participants provided their own perception of maximal exercise when performing the HIIE intervention and this can vary for any given intensity. Secondly, whilst the present study has tested two types of exercises, there are others of a similar nature that could form the basis of a full-scale trial and will be developed with input from young people themselves. In this study, participants were not familiar with wearing the gas analysis equipment and this may have elevated the respiratory values slightly when performing the exercise. Though EE is an indirect estimation and a whole room calorimeter would be required to do a direct measure, gas analysis is an accepted and more practical measure. Withstanding these considerations, our data provide a basis for designing the exercise interventions for a future trial that will address the effectiveness of different intensities for managing depression in young people.

5. Conclusions

In conclusion, to ensure the authors are comparing the effect of high intensity and low intensity exercise on depression in adolescents in the future READY trial the exercise duration for the LIE needs to be 133% of the HIIE. This is important when designing the training load for the training programme. In doing so, the current study highlights potential methodologies for researchers wanting to energy match exercise interventions for future clinical trials.

Acknowledgements: The authors would like to thank Oliver Stafford, Anna Irvine and Lauren Baker for helping with data collection. We would also like to thank all the young people who volunteered to take part as well as for their parents for their consent and transport to the laboratory.

Declarations

Author Contributions: Conceptualisation, L.B., N.H., A.C., A.J., J.J., S.W., S.M., S.S., K.I., D.T. and DT2.; methodology, L.B., N.H., A.C. and A.J.; investigation, L.B.; resources, L.B., N.H., A.C., A.J., J.J., S.W., S.M., S.S., K.I., D.T. and DT2.; data curation, L.B.; writing – original draft preparation, L.B.; writing – review and editing, L.B., N.H., A.C., A.J., J.J., S.W., S.M., S.S., K.I., D.T. and DT2.; project administration, L.B.; funding acquisition, L.B., N.H., A.C., A.J., J.J., S.W., S.M., S.S., K.I., D.T. and DT2. All authors have read and agreed to the published version of the manuscript.", please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

Funding: This study is funded by the National Institute for Health Research (NIHR) Health Technology Assessment (HTA 17/78/10). The views expressed are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care.

Code availability: Not applicable

Ethics approval: Obtained from the University of Hertfordshire ethics committee (Reference number: LMS/SF/UH/03759).

Consent to participate: Informed consent was obtained from both the parent and the adolescent.

Consent for publication: All authors consent.

Availability of data and material: Available on request to corresponding author.

References

1. Arena R, McNeil A, Street S, Bond S, Laddu DR, Lavie CJ, Hills AP (2018) Let Us Talk About Moving: Reframing the Exercise and Physical Activity Discussion. Curr Probl Cardiol 43 (4):154-179. doi:10.1016/j.cpcardiol.2017.06.002
2. MacInnis MJ, Gibala MJ (2017) Physiological adaptations to interval training and the role of exercise intensity. J Physiol 595 (9):2915-2930. doi:10.1113/JP273196
3. Taylor KL, Weston M, Batterham AM (2015) Evaluating intervention fidelity: an example from a high-intensity interval training study. PLoS One 10 (4):e0125166. doi:10.1371/journal.pone.0125166
4. Melzer K, Heydenreich J, Schutz Y, Renaud A, Kayser B, Mader U (2016) Metabolic Equivalent in Adolescents, Active Adults and Pregnant Women. Nutrients 8 (7). doi:10.3390/nu8070438
5. Jeukendrup AE, Wallis GA (2005) Measurement of substrate oxidation during exercise by means of gas exchange measurements. Int J Sports Med 26 Suppl 1:S28-37. doi:10.1055/s-2004-830512