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Respiratory responses and rating of perceived exertion of severely obese adolescents during continuous and intermittent graded walking protocols: application to cardiorespiratory field tests

Abstract

During 20 m shuttle tests, obese adolescents may have difficulty achieving maximum cardiorespiratory performance due to the presence of braking-relaunch phases (BRP). Nineteen obese adolescents aged 15.2 ± 1.5 years (body mass index [BMI] = 39.7 ± 5.9 kg.m^{-2}) performed three graded walking exercises on a 50 m track at speeds between 3 and 6 km/h: a continuous-straight-line protocol (C), a continuous protocol that required turning back every 30 sec (C-BRP) and an intermittent protocol that consisted of successively walking then resting for 15 sec (15-15). Oxygen uptake (VO_2), aerobic cost of walking (Cw), ventilation (VE) and rating of perceived exertion (RPE) were measured at each stage during the protocols. During C-BRP, the responses were not significantly higher compared with C ($p > 0.30$). During 15-15, the VO_2, Cw and VE were ~ 15 to 25% lower than during C beginning at 4 km/h ($p < 0.05$). In obese adolescents, the respiratory impact of sudden directional changes during the 20 m shuttle-type test appeared to be minor at walking speeds. During the 15-15 test, the intensity increases more progressively, and this design may encourage obese adolescents to walk further than during a continuous test.

Words: 194

Key words: obese, adolescents, 20m shuttle run test, intermittent, cardiorespiratory test

Introduction

A 40-year follow-up study conducted among thousands of individuals reported that being obese during adolescence is associated with a 3.5-fold increased risk for death from a cardiovascular event, after adjustment for individual characteristics (Twig *et al.*, 2016). Cardiorespiratory fitness (CRF) is one of the main predictors of future cardiovascular risk during adolescence and adulthood (Ortega *et al.*, 2008; Kvaavik *et al.*, 2009) and could reduce the risk of becoming overweight or obese during adolescence (Ortega *et al.*, 2011). Thus, researchers suggest that exercise training programmes should focus on improving CRF rather than losing weight (Barry *et al.*, 2014).

To maximise the benefits of the programme on an individual's CRF, the exercises must be performed at a percentage of the maximal functional respiratory capacity. Thus, the individualisation of an exercise training programme requires assessment of this parameter. This assessment aims to 1) determine the intensity that must be reached during the exercises to obtain the best results and 2) compare the CRF before and after the programme. Due to the high material cost and skills required in laboratory testing, field tests are commonly used in clinical settings to indirectly assess functional respiratory capacities (Quinart *et al.*, 2014). These tests mostly rely on graded walk/run exercises and have been extensively used in paediatric populations, including healthy-weight (Tomkinson *et al.*, 2017) and obese children (Morinder *et al.*, 2009; Vanhelst *et al.*, 2013; Quinart *et al.*, 2014). However, during continuous treadmill testing, Breithaupt *et al.* (2012) found that many obese adolescents are unable to meet at least two of the maximality criteria: peak of oxygen consumption (VO_{2peak}), heart rate > 90% of the theorical maximal value, a respiratory quotient above 1.05 and a feeling of maximal exertion. Moreover, the rating of perceived exertion (RPE) reported by obese adolescents at the end of graded tests corresponds to moderate-vigorous rather than maximal intensities, whether in the laboratory (Marinov *et al.*, 2002; Lazaar *et al.*, 2006) or the field (Rey *et al.*, 2016; Thivel *et al.*, 2017). This finding confirms their difficulty in reaching a state of total exhaustion during a maximal test.

These difficulties may result from the interaction of complex physiological and biomechanical mechanisms. In comparison to their non-obese counterparts, obese adolescents exhibit early lower limb fatigability (Garcia-Vicencio *et al.*, 2015) and reduced muscle oxidative capacities (Salvadego *et al.*, 2010; Lazzer *et al.*, 2013). These limitations lead to early shortness of breath (Mendelson *et al.*, 2012), a state that alters their aerobic performances (Norman *et al.*, 2005). From a biomechanical point of view, excess body weight decreases muscular mechanical efficiency (Rosenbaum *et al.*, 2003) and leads to an approximately 25% higher average cost of walking (Cw) due to an increased medio-lateral displacement of the centre of gravity (Peyrot *et al.*, 2009). From a psychological point of view, their RPE is apparently lower during a cycling rather than a weight-bearing exercise performed at 75% of their maximal respiratory capacities (Thivel *et al.*, 2016). This data suggests that walking or running becomes harder than cycling when the intensity crosses a certain level. This phenomenon may be associated with an increased feeling of fatigue or musculoskeletal pain during weight-bearing exercises (O'Malley *et al.*, 2012).

Due to its simplicity, the 20 m shuttle run test (20 m SRT; Léger *et al.*, 1984) remains the gold standard for field clinical assessment of respiratory fitness in children (Tomkinson *et al.*, 2017). The test consists of successively making round trips over a 20 m distance at the rate of a progressively more frequent sound signal. However, the presence of a large and increasing number of braking-relaunching phases (BRP)—a component within continuous-shuttle tests that requires stopping, turning back and re-starting the effort—limits maximal aerobic performance (Berthoin *et al.*, 1994). In athletes, the BRP results in early lactic acidosis (Ahmaidi *et al.*, 1992) and a VO_2 increase proportional to the speed (Dellal *et al.*, 2010; Hatamoto *et al.*, 2014). In obese children, the BRP impact during the 20 m SRT may be accentuated by their excess body weight and could underlie the poor maximal cardiorespiratory performances commonly observed by several authors (Nassis *et al.*, 2005; Klijn *et al.*, 2007; Castro-Pinheiro *et al.*, 2011). Moreover, Quinart *et al.* (2014) showed that the predicted VO_{2peak} obtained from the adapted 20 m SRT equation is valid when the BMI is considered, while it is underestimated when the equations proposed by Léger *et al.* (1984) are used. This study suggests that even an adapted 20 m SRT would not allow obese adolescents to achieve a valid maximal respiratory performance due to the BRP. However, a current lack of data limits our comprehension of the main cause of this limitation.

Recently, two studies (Rey *et al.*, 2016; Thivel *et al.*, 2017) validated the Spartacus test to assess maximal cardiorespiratory performances in obese adolescents. The Spartacus test is an intermittent, graded and maximal protocol characterised by successive periods of exercise and 15 sec of passive recovery. Initially developed by Rossi *et al.* (2009) to make aerobic tests less monotonous for children, this test has been successfully used in obese adolescents in order to attenuate the fatigue induced by the sudden directional changes (Rey *et al.*, 2013). Surprisingly, the Spartacus test and the 20 m SRT elicit similar maximal RPE and heart rate scores in obese adolescents (Rey *et al.*, 2013; Thivel *et al.*, 2017). However, the starting speed used in previous works (> 7 km/h) could be too high for adolescents with a higher degree of obesity (Kljin *et al.*, 2007; Vincent, 2015). Otherwise, no study has compared respiratory responses or RPE of obese adolescents during a continuous-shuttle (C-BRP) versus continuous straight-line (C) or a C-BRP versus an intermittent 15-15 walking exercise. The latter should be a more suitable form of exercise for obese adolescents.

Objective

In order to clarify the physiological mechanisms and justify the poor performances during continuous-shuttle-type tests—and to collect new data on the 15-15 exercise modality in obese adolescents—the objective of the present study was to compare respiratory (VO_2, aerobic cost of walking [Cw] and ventilation [VE]) and perceptual (RPE) responses of this population during three different submaximal graded exercise protocols.

We hypothesised that at the equivalent speed, the respiratory responses and the RPE would be significantly 1) higher during the C-BRP versus the C protocol; 2) lower during the intermittent protocol (15-15) versus the C-BRP protocol; 3) lower during the 15-15 versus the C protocol. Our secondary hypothesis was that the relationship between RPE and VO_2 will be stronger during both continuous protocols compared to the intermittent one.

Material and methods

Participants

Male and female obese adolescents from Zuydcoote Maritime Hospital's Rehabilitation Care Unit (France) were included in this study. The adolescents were hospitalised in groups of 6 to 8 individuals for 2 months (full-time accommodation from Monday to Friday) as part of a multidisciplinary management of their obesity. The inclusion criteria were: age between 12 and 17 years and obesity defined by a body mass index (BMI) located above the 97^{th} percentile of the French curves (Rolland-Cachera *et al.*, 1991).

Each participant completed a total of four visits. During the first visit, the protocol was presented to participants and their parents. During this session, height and weight were measured using a stadiometer and an impedance balance (TANITA DC-360 model) in order to calculate BMI, BMI Z-score and body composition. Ethical approval was obtained for this study by a local ethical committee. Information about the aims of this study was provided to parents and adolescents. All participants provided written informed consent to participate in the study. The research was conducted in accordance with the Declaration of Helsinki (2013).

Experimental procedure

During each follow-up visit, participants performed one of the three graded walking protocols (see Figure 1); each lasted 12 min, divided into four 3-min stages. Such a delay was considered sufficient to achieve a ventilatory steady state in this population, because children have faster oxygen uptake kinetics at exercise onset (Fawkner *et al.*, 2003), and obesity does not affect pulmonary gas exchange capacities in children (He *et al.*, 2009). The selected speeds were 3, 4, 5 and 6 km/h, which correspond to 0.83, 1.11, 1.39, 1.67 $m.s^{-1}$, respectively. Theses velocities were previously used to calculate Cw in obese adolescents (Peyrot *et al.*, 2009). In order to guide the participants, pads were placed at regular intervals (4.17 m) that corresponded to the distance covered in 15 sec at a speed of 1 km/h. A sound was emitted every 15 sec, a feature that allowed the participants to adjust their speed during the test.

For each participant, the exercises were performed over a period (at most) of 1 week, in a randomised order, at the same time of day (between 09:00 and 12:00) and interspersed by at least 24 h. The C protocol—the control condition—consisted of walking along the track without sudden directional changes at the target speeds. The C-BRP comprised walking continuously while turning back to the opposite direction every 30 sec (two signals). The BRP were performed according to the instructions provided during the familiarisation session (Hatamoto *et al.*, 2014). The instructions were to pivot inwards while leaning on their strongest foot in order to minimise balance loss during the movement. Instead of classic shuttle-type protocols with higher and increasing BRP numbers during the test, we used a continuous-shuttle protocol with two BRP per min to ensure that all participants would be able to complete the protocol. The intermittent 15-15 protocol consisted of successively walking, resting, walking back to the opposite direction and then resting. At the end of a 15-sec exercise period, the participant had to respect a 15-sec passive recovery period and then start again in the opposite direction at the next signal. The participants were accompanied by an investigator throughout the exercises to ensure compliance with the protocol. The 15-15 modality was selected because of its use during the Spartacus test.

*** Figure 1 near here ***

Data collection

Oxygen consumption

During all tests, the participants wore a respiratory gas analyser (Cosmed K4b², Italy) that was first calibrated according to the manual instructions. Prior to the start of the first exercise, the respiratory responses (VO_2, Cw and VE) associated with standing were retained as the mean values measured within the last 10 min of standing (this time would be the minimal delay required to reach a steady state VO_2 at rest; Compher *et al.*, 2006).

During exercises, VO_2, Cw and VE were averaged over the last 30 sec of each 3-min stage for C and C-BRP and over the last two 15-sec exercise periods for the 15-15 protocol.

RPE

The RPE was assessed by the participants during the last 30 s of walking for each stage. The score was based on a scale adapted to obese children (COPE-10, Quinart *et al.*, 2016). The instruction to use the ladder was provided during the familiarisation session and participants were reminded on the day of the test.

Cw calculation

From the VO_2 and speed, the Cw was calculated for each exercise modality, according to the formula of di Prampero *et al.* (1986):

$$Cw = [VO_2\ (speed) - VO_2\ (standing)]/speed \quad (1)$$

Note: Cw is expressed in $ml.kg^{-1}.m^{-1}$; VO_2 in $ml.kg^{-1}.min^{-1}$; speed in $m.min^{-1}$.

Statistical analysis

The data were analysed with R software (version 3.5.1). Normality and homogeneity of distributions were checked with the Shapiro-Wilk and the Snedecor F tests, respectively. Differences between sex for age, BMI, total mass, lean body mass and fat mass were tested with Student *t*-tests. Subsequently, the effect of the protocol and speed on VO_2 was assessed with a mixed-effects two-way analysis of variance (ANOVA; protocol * speed); repeated measures were used for both factors. Duncan's multirange post hoc test was used to compare the C to the C-BRP protocol, the C to the 15-15 protocol and the C-BRP to the 15-15 protocol. The same analysis was conducted with Cw and VE. Finally, the effect of protocol and speed on RPE was analysed with Friedman's ANOVA and Wilcoxon's matched paired tests. The relationship between RPE and VO_2 was tested with a Spearman rank-order correlation coefficient. The threshold for significance was set at $p < 0.05$.

Results

*** Table 1 near here ***

Respiratory responses

VO_2 and Cw were plotted against the protocol type and speed in Figure 2 and Figure 3, respectively. There was a significant interaction between the protocol and speed ($p < 0.001$) for all physiological parameters. Post hoc comparisons revealed that this interaction was due to a significant difference between the 15-15 and both the C and C-BRP protocols. Indeed, the VO_2 and VE observed during the C and C-BRP protocols were not significantly different from each other ($p > 0.36$ and $p > 0.30$, respectively, for all speeds). Furthermore, during the 15-15 protocol, the VO_2 and VE were 15 to 25% lower than during C at 4, 5 and 6 km/h ($p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively) and the Cw at all speeds ($p < 0.001$).

*** Figure 2 near here ***

*** Figure 3 near here ***

Psychological responses

RPE data are shown in Figure 4. According to the Friedman's ANOVA, there was no significant interaction between protocol and speed on the RPE. The overall RPE was 0.5 points higher during C-BRP compared to the 15-15 ($p < 0.05$). However, RPE was comparable between C-BRP and C ($p = 0.51$) and between 15-15 and C ($p = 0.14$).

*** Figure 4 near here ***

Relationship between respiratory and psychological parameters during the tests

Finally, we observed a significant moderate-to-strong correlation between RPE and VO_2 regardless of the exercise modality ($p < 0.001$ for the three modalities). Moreover, the correlations were stronger in the C ($r = 0.64$) and C-BRP ($r = 0.66$) protocols compared to the 15-15 protocol ($r = 0.49$).

Discussion

The first objective of this study was to measure aerobic and psychological responses during three types of graded exercises in order to identify the potential mechanisms that can limit obese adolescents during a shuttle-type graded test. To our knowledge, this study is the first that compared respiratory responses among three graded walking exercises in severely obese adolescents. The main findings of this study were: 1) The respiratory responses and RPE were not significantly impacted by the presence of two BRP per min at walking speeds in obese adolescents, according to our comparative analysis between the C and C-BRP protocols; 2) At speeds above 3 km/h, the 15-15 modality led to a 15-25% reduction in respiratory responses, with an accentuating effect of speed.

First, we hypothesised that the presence of BRP during a continuous-graded test would be associated with higher VO_2, Cw, VE and RPE in obese adolescents. Contrary to our expectations, both respiratory and psychological responses were not significantly different between the C-BRP and C protocols, despite the presence of two BRP per min at all speeds. At 6 km/h, the VO_2 reached 17.3 ± 2.3 and 17.9 ± 1.9 $ml.kg^{-1}.min^{-1}$ for the C and C-BRP protocols, respectively. Thus, VO_2 only increased 0.6 $ml.kg^{-1}.min^{-1}$ during the C-BRP protocol. In obese individuals, the lower limb muscle contractions required to move their body are disproportionately increased because they have to improve their dynamic stability to protect the knee joint (Sheehan *et al.*, 2012). During a continuous-shuttle test, the need to slow down, turn back and re-accelerate the body was hypothesised to significantly impact respiratory responses due to an overrecruitment of lower limb muscles. The presented results suggest that respiratory responses are not severely affected by the BRP in obese adolescents during walking. It is possible that for walking speeds, two BRP per min represents an insufficient stimulus to significantly increase VO_2, even in severely obese adolescents.

In athletes, the VO_2 becomes significantly higher during the 20 m SRT compared to straight-line running only at speeds above 60% of the maximal speed reached during the 20 m SRT (Buchheit *et al.*, 2011). Rey *et al.* (2016) reported a VO_{2peak} at the end of the 20 m SRT of 38 $ml.kg^{-1}.min^{-1}$ in obese adolescents. Compared to this study, those participants were of a comparable sex distribution (11 girls and 6 boys) but lower corpulence (BMI = 34.0 ± 5.3 versus 39.7 ± 5.9 in the present study). If VO_{2peak} is estimated at ~30 $ml.kg^{-1}.min^{-1}$ in the present population, the intensity of the protocol likely reached ~ 60% VO_{2peak} at 6 km/h, a value that should correspond to the intensity required to detect a significant BRP effect on VO_2 during the 20 m SRT. However, during the 20m SRT (or its adapted version for obese children with a starting speed of 4 km/h, validated by Quinart *et al.*, 2014), the BRP number per min is higher than in our protocol and increases proportionally with the speed of movement: from three at 4 km/h to five at 6 km/h. Considering this difference and the low observed RPE scores, it is possible that the speeds reached during the protocol were insufficient to detect any significant impact of the BRP on respiratory responses. It is also possible that during walking, the relative impact of BRP on VO_2 is lower than during running. Otherwise, at the time of the study, adolescents were participating in a daily exercise re-training programme based on light-to-moderate continuous exercise. The fatigue induced by these exercises may have increased the interindividual variability in the results, but we randomised the order of experiments so that this experimental bias was identical for each participant. Nevertheless, it should not be excluded that the limiting impact of BRP involves other physiological mechanisms that were not measured for practical reasons. First, some authors demonstrated that shuttle-running is associated with increased used of anaerobic metabolism (Ahmaidi *et al.*, 1992; Buchheit *et al.*, 2011). Second, obese adolescents are characterised by increased lower limb fatigability (Garcia-Vicencio *et al.*, 2015) as well as impaired muscle oxidative capacities (Lazzer *et al.*, 2013). Thus, the excessive recruitment of motor units would lead to the premature apparition of neuromuscular fatigue (Ratel *et al.*, 2006) that would limit the continuation of the effort despite the fact that the cardiorespiratory system is still far from being limited. These muscular mechanisms, however, were not studied here, a deficiency that limits the current interpretation of our results.

Obese adolescents have difficulty achieving a maximal cardiorespiratory state (Thivel & Aucouturier, 2015), especially during exercises that require body weight support, such as walking and running (Nantel *et al.*, 2011). Continuous-shuttle tests are commonly used to assess functional aerobic capacities in obese children (Klijn *et al.*, 2007; Quinart *et al.*, 2014). Yet, these tests are difficult for this population. Although the difficulties associated with these tests are mentioned in several studies in the obese child (Nassis *et al.*, 2005; Klijn *et al.*, 2007; Castro-Pinheiro *et al.*, 2011), none of them was interested in the physiological mechanisms that explain these limitations. Thus, measuring both physiological and psychological responses during shuttle versus straight-line walking/running tests may highlight the potential mechanisms that can limit obese adolescents during the 20 m SRT and other shuttle-type exercises.

The second objective of the study was to compare the respiratory responses and RPE during an intermittent 15-15 protocol versus the C and C-BRP protocols at the same speeds (3-6 km/h). The intermittent 15-15 modality was used to design the Spartacus test, a graded intermittent protocol for evaluating aerobic functional capacities that has been validated in obese adolescents (Rey *et al.*, 2016; Thivel *et al.*, 2017). In line with our expectations, during 15-15, the VO_2 was significantly lower than during the C and C-BRP ($p < 0.05$ to $p < 0.001$) at speeds above 3 km/h. These differences would correspond to 28, 34 and 44% of the estimated VO_{2peak} for this population at 4, 5 and 6 km/h, respectively. These estimates suggest that 15-15 walking at speeds < 7 km/h is a light-intensity exercise for most severely obese adolescents; the addition of a previous landing at 6 km/h could thus make the Spartacus test more accessible to adolescents who are severely obese. Intriguingly, the intensity of the effort appeared to increase more gradually during the 15-15 compared to the C and C-BRP protocols, despite the similar speed and stage durations. The more progressive nature of the 15-15 protocol could thus make it possible to more precisely identify the speeds that correspond to work intensities, a measure that is of major clinical interest.

During the passive recovery periods, the oxygen debt induced by the previous bout of exercise can be partially paid back, a phenomenon that would reduce breathlessness during the following bout of exercise. Whereas respiratory discomfort is a main limiting factor in obese individuals (Marinov *et al.*, 2002), a short-interval-based-protocol could help them to produce a cardiorespiratory test under more favourable respiratory conditions. From this perspective, the 15-15 modality may be a strategy to delay fatigue in obese adolescents (Thivel *et al.*, 2017) and encourage them to continue the test more than they would during the 20 m SRT. However, Rey *et al.* (2016) found that cardiorespiratory responses at the end of the test are not significantly different between the 20 m SRT and Spartacus test in obese adolescents. Although the Spartacus test induces a greater feeling of physical competence in this population (Rey *et al.*, 2016), further comparisons between these two tests are needed to establish a scientific consensus as to which one more precisely assesses the maximum aerobic capacities of obese adolescents.

Finally, the RPE was assessed with the COPE-10, which was recently validated in obese youth (Quinart *et al.*, 2016). Contrary to our expectations, there were no statistical differences between the 15-15 and either the C or C-BRP protocols regarding the RPE. With regards to the respiratory parameters, the stimulus provided by each protocol was probably insufficient to induce significant differences in the RPE score. This supposition was confirmed by the fact that the highest RPE observed in each protocol corresponded to moderate intensities (i.e., 3 to 4 out of 10 on the COPE-10 scale). Besides, the present results confirmed that the RPE assessed with COPE-10 is strongly associated with VO_2 in obese adolescents (Quinart *et al.*, 2014); however, the relationship between RPE and VO_2 has not yet been studied during intermittent exercises in this population. This information would enable researchers and clinicians to determine under which exercise conditions the RPE is the lowest for a given intensity. On the other hand, it would also allow one to check whether this tool makes it possible to precisely target a work area during intermittent exercise. As expected, the relationship between RPE and VO_2 was weaker in the 15-15 ($r = 0.49$) compared to the C ($r = 0.64$) and C-BRP ($r = 0.66$) protocols ($p < 0.001$ for all protocols). The intermittent nature of the effort during 15-15 may cause more difficulty for obese adolescents to assess the intensity of their effort as precisely as during a continuous exercise.

Our results, and those from previous studies, suggest that intermittent modality exercises, with or without BRP, could promote adherence to physical activity programmes in obese adolescents. These exercises characterise many indoor disciplines, including team sports, and would allow significant improvements in aerobic capacities (Thivel *et al.*, 2019) while promoting long-term maintenance of the obtained benefits (Tjönna *et al.*, 2009). Thus, the inclusion of these activities in an exercise training programme for obese adolescents—who are clinically able to perform field activities—appears to be justified both physiopathologically and psychologically. Overall, these results suggest that 1) poor performances during continuous shuttle-type tests in obese adolescents involve more muscular rather than respiratory factors and 2) the 15-15 modality may represent an intriguing alternative to the continuous test to encourage obese adolescents to achieve maximal respiratory effort.

Limitations and future perspectives

Our study has some limitations. First, paediatric obesity is a pathology characterised by many physiological and psychosocial factors that led to high individual variability in anthropometric characteristics and psychophysiological responses to the protocols in this study. In this context, studying the impact of individual factors, including training status, sex or maturation, on the studied parameters would require classifying adolescents according to their size, sex and maturation. However, the objective of this study was to compare respiratory and perceptual responses to different incremental protocols for a group of severely obese adolescents; the impact of individual factors on these parameters may be the subject of a future study with a larger sample. The variability in the age and degree of obesity among adolescents following a hospital-based treatment programme have already been discussed by Rey *et al.* (2016). These factors must be considered when an exercise training programme is conducted with a group. Second, our interpretation is limited to submaximal data; it would be interesting to measure the maximal cardiorespiratory responses as a function of the type of protocol. Finally, body composition was assessed using impedancemetry, which is not accurate in severely obese adolescents (Thivel *et al.*, 2018).

Conclusion

In conclusion, the presence of two BRP per min did not significantly impact the respiratory responses or RPE at speeds between 3 and 6 km/h. During 15-15 walking, the respiratory responses were significantly lower than during the C and C-BRP protocols at 4, 5 and 6 km/h ($p < 0.05$, $p < 0.01$ and $p < 0.001$, respectively). RPE was generally unaffected by the protocol. Finally, the relationship between RPE and VO_2 was greater in the C ($r = 0.64$, $p < 0.001$) and C-BRP ($r = 0.66$, $p < 0.001$) compared to the 15-15 protocol ($r = 0.49$, $p < 0.001$). The respiratory impact of sudden directional changes during a 20m SRT would be minor at walking speeds. In comparison to continuous protocols, the 15-15 protocol allows obese adolescents to reduce their respiratory responses by 15-25% at speeds above 3 km/h.

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Conflict of interest

The authors report no conflict of interest.

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Table 1. Participant characteristics, presented as mean ± standard deviation (SD) values.

	Girls (n = 12)	Boys (n = 7)	Total (n = 19)
Age (yrs)	15.7 (1.1)	14.4 (1.6)	15.2 (1.5)
BMI ($kg.m^{-2}$)	39.4 (4.7)	40.2 (7.7)	39.7 (5.9)
Z-Score BMI (SD)	2.4 (0.2)	2.6 (0.3)	2.5 (0.2)
Total mass (kg)	103.0 (14.2)	117.1 (33.6)	108.2 (24.3)
Lean mass (%)	53.5 (2.8)	59.6 (8.2)	55.7 (6.2)
Fat mass (%)	46.4 (2.8)	40.4 (8.2)	44.3 (6.2)

Figure 1: Representation of the three protocols for 1 min of exercise. Abbreviations: run = exercise; rec = passive recovery; C = continuous walking ; C-BRP = continuous walking that require turning back every 30 seconds; 15-15 = successive periods of walking and passive recovery of 15 seconds.

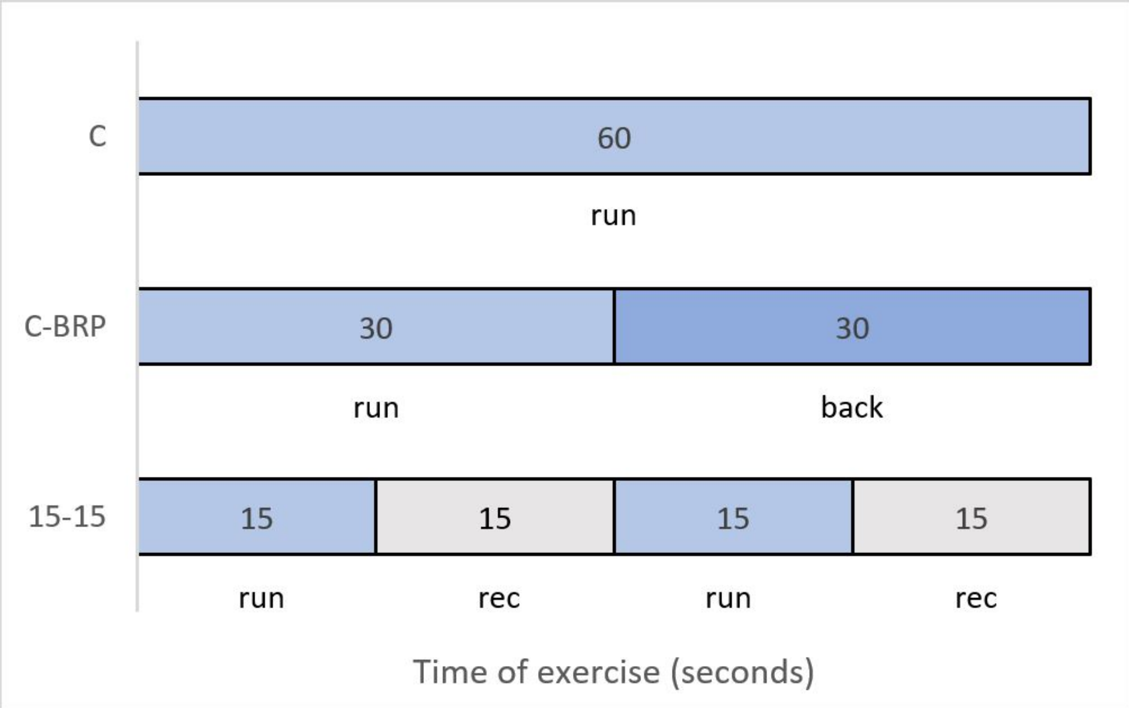

Figure 2. Oxygen uptake (VO_2) as a function of speed for each protocol. Differences between 15-15 and C: * ($p < 0.05$); ** ($p < 0.01$); *** ($p < 0.001$). Differences between 15-15 and C-BRP: ° ($p < 0.05$); °° ($p < 0.01$); °°° ($p < 0.001$).

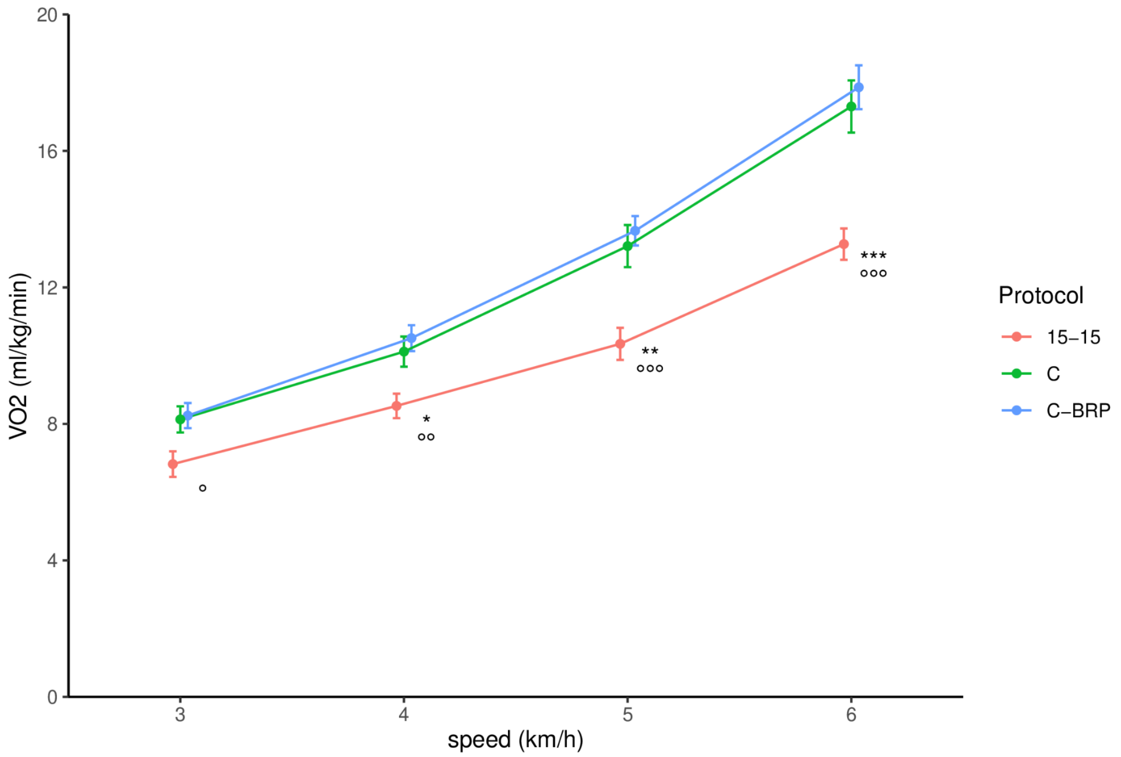

Figure 3. Aerobic cost of walking (Cw) as a function of speed for each protocol. Differences between 15-15 and C: * ($p < 0.05$); ** ($p < 0.01$); *** ($p < 0.001$). Differences between 15-15 and C-BRP: ° ($p < 0.05$); °° ($p < 0.01$); °°° ($p < 0.001$).

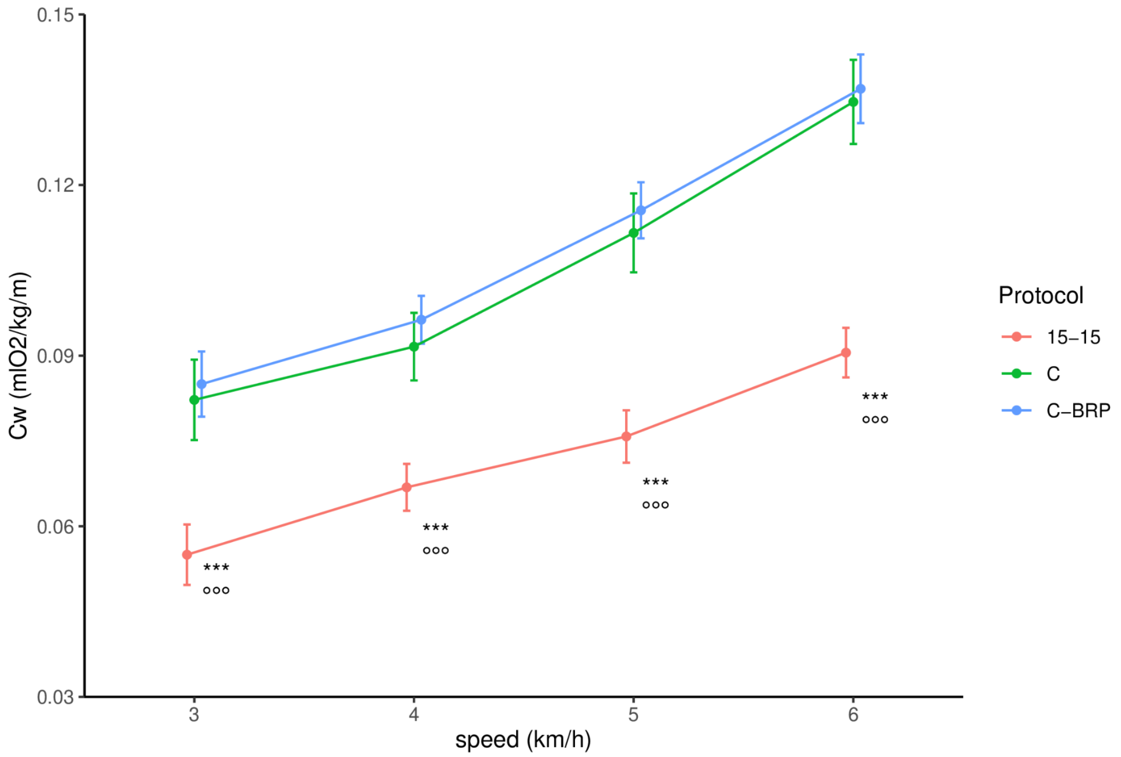

Figure 4. Rating of perceived exertion (RPE) as a function of speed for each protocol. Differences between 15-15 and C: * ($p < 0.05$); ** ($p < 0.01$); *** ($p < 0.001$). Differences between 15-15 and C-BRP: ° ($p < 0.05$); °° ($p < 0.01$); °°° ($p < 0.001$).