Is rating of perceived exertion a valid method for monitoring exergaming intensity in type-1 diabetics? A cross-sectional randomized trial.

Is rating of perceived exertion a valid method for monitoring exergaming intensity in type-1 diabetics? A cross-sectional randomized trial.

Jorge Luiz de Brito Gomes[a,d], Pooya Soltani[b], Rhennan Rodrigues Barbosa[c], José Adevalton Feitosa Gomes[d], Manoel da Cunha Costa[c,d]

[a] Department of Physical Education, Federal University of Vale do São Francisco, Petrolina, Brazil
[b] School of Digital, Technologies and Arts, Staffordshire University, Stoke-on-Trent, UK
[c] High School of Physical Education, University of Pernambuco, Recife, Brazil
[d] Department of Physical Education, Rehabilitation and Functional Performance, Universidade de Pernambuco, Petrolina, Brazil

Abstract

Aims: The rating of perceived exertion (RPE) provides correlations with physiological measurements of exercise intensity, including metabolic equivalent (MET), oxygen consumption ($\dot{V}O_2$), and heart rate (HR), in real (RS) and virtual (VS) sessions. To use RPE in patients with pathology, we aimed to examine the concurrent validity of RPE in type-1 diabetes mellitus (T1DM) patients while exergaming. **Methods**: Ten T1DM patients performed two 30-minute crossover sessions of moderate-intensity exercise (washout 72–196h). The RS group performed running, and the VS group played the *Kinect Adventures!* video game. METs were measured by a direct gas analyzer during the sessions, and RPE was measured on the 6-20 point Borg scale after the sessions. **Results**: RS and VS showed similar RPE (13.2 ± 2.7 vs. 14.2 ± 2.4) and MET (4.6 ± 1.1 vs. 4.0 ± 0.8) values ($p > 0.05$). RPE vs. MET correlation-coefficients were large in RS ($r = 0.64$; $R^2 = 41$; $p = 0.04$) and were moderate in VS ($r = 0.42$; $R^2 = 18$; $p = 0.22$). Additionally, RS secondary values ($\dot{V}0_2$ and HR vs. RPE) showed high coefficients ($\dot{V}0_2$-r = 0.62; average HR-r = 0.62; maximal HR-r = 0.50, $p < 0.05$). VS secondary values, on the other hand, showed low-moderate coefficients ($\dot{V}0_2$-r = 0.42; average HR-r = 0.23; maximal HR-r = 0.21, $p > 0.05$). **Conclusion**: The current validation showed that RPE may not be a valid and strong method for T1DM patients while exergaming. Healthcare professionals should cautiously use the 6 – 20 point RPE scale in pathological patients, specifically in T1DM while exergaming.

Keywords: Perception; Metabolic Equivalent; Diabetes Mellitus; Exercise; Video Games; Blood Glucose.

Introduction

The exercise guidelines recommend weekly aerobic, anaerobic, or combined activities, in healthy and those with diabetes mellitus (DM; Colberg et al., 2015). However, several factors including changes in blood glucose and lower levels of enjoyment, hinder adherence to exercise among individuals with DM (Colberg et al., 2015; Theng et al., 2015). Active video games (exergames) and virtual reality (VR) are the recent exercise trends that can provide motivation to participants (Novak & Soyturk, 2021; Ramírez-Granizo et al., 2020; Soltani et al., 2021) and might increase their adherence to physical activity (Brito-Gomes et al., 2020; Levac et al., 2017; Mellecker et al., 2013; Paim da Cruz Carvalho et al., 2021). Light to vigorous-intensity exergaming sessions may also benefit type-1 and type-2 diabetes patients, including reductions in glycated hemoglobin and improvements in cardiovascular and other health-related outcomes (Brinkmann et al., 2017; DeSmet et al., 2014; Perrier-Melo et al., 2015).

Unlike type-2 diabetics, severe changes in glycemia (i.e., hypo or hyperglycemia) may occur in T1DM patients. Without correct management, the disease can lead to secondary issues (Akturk et al., 2018; Hashimoto et al., 2014; Riddell & Perkins, 2009; Yardley & Colberg, 2018). Therefore, these patients need to control their blood glucose regularly, both before and after exercise (ADA, 2019; Colberg et al., 2016). The prescribed exercise intensity, whether real or virtual, should also be regulated (ADA, 2019; Brito-Gomes, Perrier-Melo, Oliveira, et al., 2015; Colberg et al., 2015, 2016; Garber, Blissmer, Franklin, et al., 2011). Traditionally, metabolism assessment, such as the metabolic equivalent (MET), was considered as the gold standard methodology for prescribing the exercise intensity and preventing complications in T1DM patients (Brito-Gomes, 2021; Garber, Blissmer, Deschenes, et al., 2011). However, this approach is not a low-cost solution and requires specific training and time for implementation. Consequently, using such a methodology may not be feasible in real-life gym settings or patients' homes.

To overcome the limitations associated with direct metabolic assessment, indirect parameters of training intensity could be monitored (Borg, 2000; Garber et al., 2011). Previous studies have used the relationship between heart rate (HR) and rate of perceived exertion (RPE) to validate the physical effort in healthy individuals during various exercise modalities (RS and VS), durations (minimum of 10 minutes), and intensities (0–3 METs: light, 3–6 METs: moderate, and > 6.0 METs: vigorous; Brito-Gomes, Perrier-Melo, Wikstrom, et al., 2015; Lau et al., 2015; Pereira et al., 2017). In diabetic patients, while HR has been identified as an important physiological variable for measuring the exercise intensity (Delevatti et al., 2015), it may not be correlated to the RPE values during exergaming (Brinkmann et al., 2017). Additionally, MET and HR might not provide a practical means of measuring exercise intensity in real-world environments such as care homes and patients' residences. These measures could also be influenced by individual differences, lack precision and scope, and may be prone to inaccuracies due to variations in the type of equipment used. However, a 6–20 point RPE scale could serve as a low-cost instrument and potentially yield correlations with physiological measurements of aerobic exercise intensity (Borg, 2000; Garber et al, 2011). Therefore, to determine whether RPE could be a better parameter for measuring VS intensities, we aimed to examine the concurrent validity of RPE in T1DM patients during exergaming.

Methods

Study type and ethical aspects

This study employs a cross-sectional design and is part of a registered crossover randomized clinical trial (Number: U1111-1194-370). This study was approved by the local ethics committee (Protocol number: 029770/2016), and prior to commencement of testing, participants or their legal guardians provided their consent by signing the consent form. All participants were informed in accordance with the Declaration of Helsinki protocol.

Inclusion and exclusion criteria and sample size calculation

The inclusion criteria were as follows: (1) having T1DM with regular use of insulin for at least 1.5 years; (2) not having other comorbid conditions; (3) not using depression medications; and (4) maintaining reasonable and controlled glycated hemoglobin (7.0–12.0 %) similar to real-life T1DM conditions. Participants were excluded if they: (1) did not complete all sessions; (2) consumed psychotropic medication or engaged in exercise therapy during the study; or (3) experienced osteomyoarticular injuries. The a priori sample size calculation was conducted using G*Power 3.1.9 software (Faul et al., 2007), with $\alpha = 0.05$, power $(1-\beta) = 0.9$, and a (very) large effect size (ES = 0.8). Consequently, considering the correlation between two variables (RPE vs. MET) in two crossover randomized sessions (RS and VS), a minimum of ten participants were needed.

Study design

A randomized, counterbalanced, crossover study was employed to devise the concurrent validation protocol. On the first day, baseline data was collected, and participants underwent equipment familiarization (30-minute sitting). After a 24-hour interval, on the second day, cross-over randomization of sessions, blood analysis, and maximal $\dot{V}O_{2peak}$ test were performed. Subsequently, on the third and fourth days, RS and VS sessions were randomly carried out with moderate intensity (3–6 METs) for a duration of 30 minutes.

Recommendations to avoid methodological bias

To prevent methodological bias, we controlled the conditions, both prior the study and before each session. The laboratory's temperature and relative humidity were maintained at 22 ± 24°C and 40 ± 60%, respectively. Participants received specific instructions: (1) to maintain their regular daily nutrition; (2) to abstain from alcohol, caffeine, or other stimulants for a minimum of 24 hours; (3) to adhere their usual sleep patterns and daily activities, excluding their structured exercises; and (4) to report any factors that might influence their physical or cognitive performance (such as injuries and emotional issues).

Procedures and techniques

Day 1 – Baseline data collection and familiarization-resting session

On the first day, we collected basic anamnesis, conducted body composition assessments (using dual-energy X-ray absorptiometry; QDR 4500W, Hologic, USA), and recorded basic anthropometric measurements (weight, height, and BMI). Before proceeding with familiarization, participants underwent scaling and exercise-memory-anchoring instructions, aimed at ensuring accurate responses during the crossover randomized sessions. The 6–20 point Borg RPE scale has 15 numerical categories, accompanied by verbal and pictorial descriptors, providing a scalar representation of various levels of physical exertion. Points ranging from six to eight indicate very light effort (e.g., resting or daily activities), while 18 to 20 points indicate near-maximum effort (e.g., maximal sprint or the ending of the $\dot{V}O_{2peak}$ test; Garber, Blissmer, Deschenes, et al., 2011). The other points between these two reference points correspond to light-moderate-vigorous intensities (9 to 11, 12 to 13, and 14 to 17 points, respectively), as per recommendations (Borg, 2000; Garber et al., 2011). To reduce the risk of bias, a sole instructor reported and linked the scale numbers to distinct everyday situations using memory-anchoring. The scaling and memory-anchoring instructions were reviewed before the crossover randomized RS and VS sessions to ensure participants accurately recalled the feelings experienced. Subsequently, T1DM patients were instructed to self-report their RPE number with as much accuracy and honesty as possible, with an understanding that there were no correct or incorrect numerical category responses. During the familiarization phase, participants remained seated in a comfortable chair for 30-minutes, refraining from conversations, screen usage (such as TV, smartphones, or sedentary video games), and other distractions. They maintained both feet on the ground and were advised to remain awake while relaxing.

Day 2 – Blood analysis, maximal oxygen consumption, and randomization of sessions

On the second day, blood samples were collected, and glycated haemoglobin (HbA1c) was measured using a semi-automatic cation exchange high-pressure liquid chromatography method. Following this, participants' $\dot{V}O_{2peak}$ was measured using a metabolic analyzer (Quark CPET, Cosmed, Italy). The protocol consisted of a two-minute warm-up at 5km/h, after which the intensity was continuously increased by 1km/h until maximum voluntary fatigue was reached (Brito-Gomes et al., 2020). HR and respiratory variables were continuously measured and recorded throughout the protocol. The test was terminated based on the demonstration of at least two of the following criteria: (1) plateau or decrease in $\dot{V}O_2$ despite rising speed intensity; (2) respiratory exchange coefficient equal to or exceeding 1.15; and (3) reaching the 95% of the maximum HR predicted by age (220 - age) or RPE between 19-20 points. The highest recorded $\dot{V}O_2$ value before the discontinuation was designated as the $\dot{V}O_2$peak. Subsequently, the counterbalanced randomization method was performed by allocation using a website randomizer, resulting in 50% of the volunteers commencing with the RS, while the remaining initiated with the VS, maintaining a 1:1 ratio.

Days 3 and 4 – Cross-over randomized sessions

The RS session involved treadmill running with a 1:1 minute-ratio, targeting 40 - 59 % $\dot{V}O_{2peak}$, as per recommendations outlined by Garber et al., 2011. Each matched moderate-intensity interval (3-6 METs) was performed for one minute, amounting to a total duration of 30 minutes. The VS session had similar characteristics to the RS session in terms of peak intensity and recovery intervals. Participants played with Xbox 360 Kinect game console (Microsoft, USA) and *Kinect Adventures!*

game (Microsoft Game Studios, USA). This game utilizes large muscle groups and could reach intensity session values according to recommendations (Brito-Gomes, Perrier-Melo, Oliveira, et al., 2015). Within this session, participants played three mini-games of River Rush, Rally Ball, and Reflex Ridge for 30 minutes (10 minutes per game). Similar to the previous study, activities such as jumps, squats, and lateral shifts involving vertical, and horizontal shoulder extension were performed across all mini-games (Brito-Gomes, 2021; Brito-Gomes et al., 2019).

Primary outcomes comparison (RPE vs. MET)

RPE was self-reported by T1DM patients to assess their physical, cardiovascular (tachycardia/bradycardia), and respiratory (hyperventilation) efforts according to recommendations (Borg, 2000; Pereira et al., 2017; Ramírez-Granizo et al., 2020). Perceived exertion was defined as "*How tired did your body feel while you were performing real or virtual exercises, analyzing your perception of cardiorespiratory and skeletal muscles?*" (Brito-Gomes et al., 2019). Furthermore, the metabolic analyzer was used to measure a 30-minute-average MET value for each T1DM patient.

Secondary outcomes (HR and $\dot{V}O_2$ vs. RPE)

During both exercise sessions, average and maximal HR and $\dot{V}O_2$ were continuously measured, with a 30-minute average value calculated for each T1DM patient.

Blood glucose safety

For T1DM patients, it is very important to verify the safety of the session by maintaining their blood glucose levels. Therefore, capillary blood glucose levels (before and immediately after the sessions) was assessed using a portable glucometer (Accu-check Active, Roche, Brazil; Colberg et al., 2016). Participants performed exercise sessions only if their capillary glycemia ranged between 100 to 250 mg/dL; should the levels fall between 100 to 139 mg/dL, carbohydrates were consumed before the exercise. Otherwise, exercise sessions were terminated or rescheduled within 48 – 72 h timeframe. After each session, participants left the room only if their capillary glycemia returned to normal values, adhering to established recommendations (ADA, 2019). The pre-post Δ% blood glucose was also used for comparative analysis.

Statistical analysis

Physiological data were presented as mean ± SD. Normality of variance were checked using Shapiro-Wilk test, and in cases of abnormal distribution, alternative statistics were applied. Primary outcomes (METs and RPE) and secondary outcomes ($\dot{V}O_2$, average and maximal HR, and pre-post Δ blood glucose values) across all conditions (Sitting, RS, and VS) were analyzed using analysis of variance (ANOVA) with repeated measures (RM). The level of statistical significance was set to 0.05. Values were also scanned when grouped collectively and based on gender to mitigate potential bias. Effect sizes (η_p^2) were considered as 0.02 small, 0.13 moderate, and 0.26 large for ANOVA RM test (Cohen, 1988). For RPE validation, separate linear regression analyses were performed for each exercise condition to establish the correlation between RPE and MET values. Concurrent validation was considered "achieved" if the Pearson correlation coefficient (PCC) values were $r \geq 0.50$ (indicating a large effect size), inline with recommendations (small: $r = 0.1 - 0.29$ and moderate: $r = 0.29–0.49$; Cohen, 1992).

Results

Ten T1DM patients participated in the study, and there were no drop-outs after the commencement of the study protocol. The baseline characteristics and secondary values for the T1DM patients are presented in Table 1. Prior to the primary outcome analysis, no sex differences were observed in MET and RPE values during any of the sessions (RS, VS, Familiarization; $p > 0.05$). Subsequently, the participants were grouped.

Table 1. Baseline characteristics and secondary outcomes data for T1DM patients during the sessions (n=10).

	Mean ± SD		
Age (years)	24.9 ± 7.5		
BMI (kg.m $^{-2}$)	21.5 ± 2.0		
Lean mass (kg)	45.4 ± 5.5		
Fat mass (kg)	12.4 ± 2.9		
Glicated Hemoglobin (%)	8.6 ± 1.4		
Diagnostic time (years)	11.5 ± 7.4		
Sex (patients number)	7 male, 3 female		
$\dot{V}O_{2peak}$ (ml.kg.min $^{-1}$)	37.4 ± 6.6		
Insulin delivery characteristics			
Basal (U/day)	26.4 ± 7.4		
Ultrarapid (U/day)	21.6 ± 9.9		
	Interventions comparison		
Secondary outcomes data	Familiarization	Real Session	Virtual Session
Maximal HR (bpm)	104 ± 14	154 ± 19*	176 ± 21*
Average HR (bpm)	83 ± 11	133 ± 14*	132 ± 12*
Oxygen consumption (ml.kg.min $^{-1}$)	4.0 ± 0.7	15.9 ± 4.0*	13.9 ± 2.8*
Pre-post Δ (mg.dL $^{-1}$)	7 ± 24	-59 ± 31*	-41 ± 32*

BMI: Body mass index; HR: Heart rate; $\dot{V}O_{2peak}$: Maximal oxygen consumption measured by $\dot{V}O_{2peak}$ test; Pre-post Δ: Variations of blood glucose; RPE: Rating of perceived exertion; *: $p < 0.05$ compared to familiarization.

There was a statistically significant difference between familiarization and activity sessions; during familiarization, MET values were lower than in RS and VS (1.1 ± 0.2 vs. 4.6 ± 1.1 and 4.0 ± 0.8; $F(2,27) = 72.0$; $p < 0.001$; $\eta_p^2 = 0.98$; Large ES). Similarly, RPE values during familiarization were statistically significantly lower than in RS and VS (7.1 ± 1.1 *vs.* 14.2 ± 2.4 and 13.2 ± 2.7 points; $F(2,27) = 27.3$; $P < 0.001$; $\eta_p^2 = 0.76$; Large ES). Conversely, no statistical differences were observed between RS and VS sessions ($p > 0.05$). Secondary outcomes, on the other hand, differed between RS and VS sessions (maximal HR (F(2,27) = 55.3; p < 0.001; η_p^2= 0.86), average HR (F(2.27) = 79.1; p < 0.001; η_p^2 = 0.90), oxygen consumption (F(2,27) = 63.4; P< 0.001; η_p^2 = 0.87), and Δ blood glucose pre-post (F = 9.9; P < 0.001; η_p^2 = 0.53)). Lastly, when assesing the concurrent validation of RPE vs. MET values in different exercise modalities, the RS session confirmed a large PCC with statistical significance (r = 0.64 [95% IC: 0.2–0.9]; R^2 = 41; p = 0.04). However, the VS session displayed a moderate PCC without statistical significance (r = 0.42 [95% IC: -0.3–0.8]; R^2 = 18; p = 0.22; Figure 1).

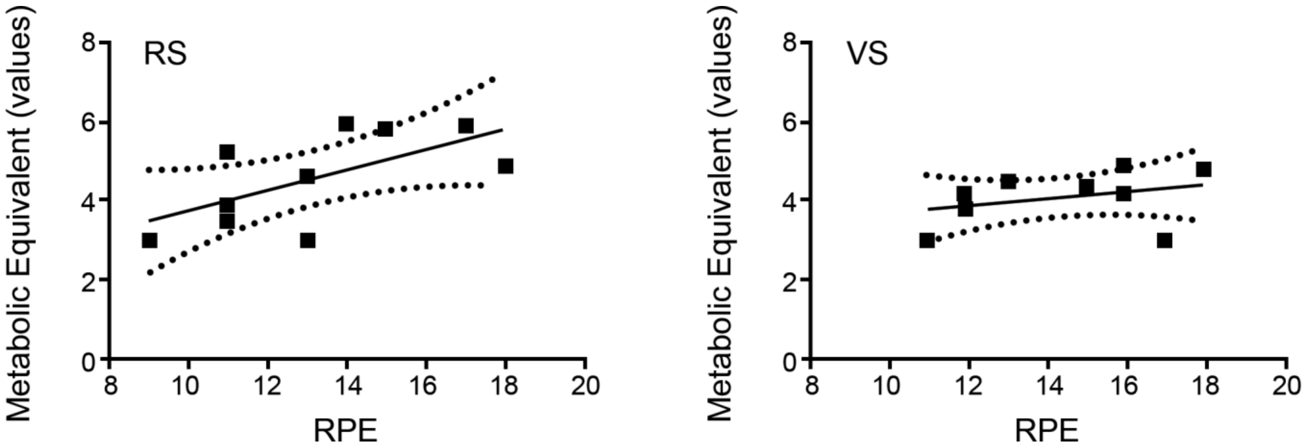

Figure 1. Regression data (RPE *vs.* MET) in RS and VS.
Note 1: RS: r = 0.64 [95% IC: 0.2 – 0.9]; R^2 = 41; p = 0.04 (Large PCC);
Note 2: VS: r = 0.42 [95% IC: -0.3 – 0.8]; R^2 = 18; p = 0.22 (Moderate PCC).

Additional regressions were conducted to compare RPE with other metabolic and physiological variables (HR and $\dot{V}O_2$) in RS and VS sessions. During RS, the PCC value for RPE vs. average HR was 0.62 [95% IC: -0.02–0.90]; R^2 = 38; p = 0.05 (Large PCC). The PCC value for RPE points vs. maximal HR was 0.5 [95% IC: -0.2–0.86]; R^2= 25; p = 0.15 (Large PCC). Lastly, the PCC value for RPE points vs. oxygen consumption was 0.62 [95% IC: -0.02–0.89]; R^2 = 38; p = 0.05 (Large PCC). During VS, the PCC for RPE vs. average HR was 0.23 [95% IC: -0.47–0.75]; R^2 = 5; p = 0.53 (Moderate PCC). The PCC for RPE vs. maximal HR was 0.21 [95% IC: -0.48–0.74]; R^2 = 4; p = 0.55 (Small PCC). Lastly, the PCC values for RPE vs. $\dot{V}O_2$ was 0.42 [95% IC: -0.29–0.83]; R^2 = 18; p = 0.22 (Small PCC).

Discussion

This cross-sectional randomized trial aimed to examine the concurrent validity of the correlation between 6-20 points RPE scale and metabolic values for T1DM patients who participate in real and virtual exercise modalities. The RPE and MET values were strongly correlated in real exercise but were moderately correlated during the virtual exercise session. In addition, the RPE correlations with other metabolic and physiological variables were mostly low and lacked statistical significance during the virtual exercise.

RPE vs. METs: Current validation in T1DM patients

We showed that under similar exercise intensities and durations, the correlation between RPE and MET values was stronger during the RS compared to the VS session. Therefore, knowledge of RPE in the context of RS would better account for variances in METs for T1DM patients (41% in RS and only 18% in VS). Our results are partially in contrast with the previous research, where RPE could indirectly estimate METs not only during different exercise modalities, but also exercises with different durations and intensities (Barbosa et al., 2017; Brito-Gomes et al., 2016, Brito-Gomes et al., 2018; Lau et al., 2015; Pereira et al., 2017; Perrier-Melo et al., 2017; Ramírez-Granizo et al., 2020). Several parameters might have contributed to perceptual responses being less coherent with the expected metabolic values. The inclusion of video, music, and immersive human-computer interaction in the game, could have altered players' perception of activity intensity (Brito-Gomes, 2021; Lau et al., 2015; Soltani & Salesi, 2013). Conversely, the game mechanics featured various non-active periods, including waiting for the game to load, watching tutorials, and advancing to next levels. Consequently, patients' cumulative METs were lower compared to RS, where continuous running occurred uninterrupted.

RPE vs. other physiological parameters

Unlike previous studies that established correlations between RPE and HR to indirectly estimate METs during different exercise modalities, durations, and intensities (Barbosa et al., 2017; Brito-Gomes et al., 2016; Pereira et al., 2017; Perrier-Melo et al., 2017), our study showed the correlations between RPE and secondary outcomes were generally of low to moderate, and mostly lacked statistical significance. It seems that RPE might not predict changes in HR and oxygen consumption similar to healthy participants during exergames. Within T1DM patients, our results suggested that RPE responses can physiologically explain the changes in HR and $\dot{V}O_2$ by approximately 25-38% during RS and only 4-18% during VS. On the other note, maximal HR was slightly higher during VS which could be related to the type of activity (e.g., sport, dance, functional training, etc.), time of measurement (e.g., mid-session or session-end), heightened demands of the game (e.g., targeting upper or lower body muscles) and increased human-computer interaction (Brito-Gomes et al., 2018). In this study, game mechanics and extended rest intervals might have contributed to lower HR and $\dot{V}O_2$ during exergaming. Previous research has also suggested that these rest intervals could range between 28 to 65% of total gameplay depending on the game and players' experience (Soltani et al., 2017).

Clinical relevance and limitations

Considering the costs for monitoring HR (e.g., electrocardiograph and heart rate monitor), MET and $\dot{V}O_2$ (e.g., gas analyzer), one might consider using RPE as an alternative. We confirmed that RPE values were strongly correlated in RS for T1DM patients. Therefore, it is crucial to exercise caution when extending its use to other exercise modalities, specially virtual sessions, as they may not accurately reflect the actual physiological and metabolic intensity of the exercise. Healthcare professionals who want to incorporate virtual sessions with exergame into their practice, should cautiously use the 6-20 RPE scale in pathological patients, specifically those with T1DM.

We would like to note some limitations associated with this current research. Firstly, only a single exergame was used in the VS, and future studies should explore more games with different types of activities. Secondly, a single moderate exercise intensity (3 to 6 METs) for both RS and VS was used, and future studies should analyze different intensities (such as vigorous intensities exceeding 7 METs). Thirdly, we used the 6-20 Borg scale; future studies could explore whether other scales (e.g., the 0-10 points Borg scale) might yield different correlations with physiological outcomes. Fourthly, while male and female patients were not statistically different, future studies should consider gender as a potential moderator when interpreting the results. Lastly, those who intend to interpret the results in a clinical context should consider which one of correlation or significance matters most to them. In terms of statistical significance, an increase in sample size could potentially alter the correlation magnitude and potentially yield different relationship in clinical and practical applications.

Conclusions

The current validation study has shown that 6 to 20 points on the RPE scale have low to moderate correlations with physiological variables during exergame sessions. Consequently, this scale might not be a valid and strong approach for estimating exergaming intensity in T1DM patients.

Conflict of interest

None declared.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Funding information

None declared.

References

ADA - American Diabetes Association. (2019). Obesity management for the treatment of type 2 diabetes: Standards of medical care in diabetes - 2019. *Diabetes Care*, *42*(Suppliment 1), S81-S89. doi: 10.2337/dc19-S008

Akturk, H. K., Rewers, A., Joseph, H., Schneider, N., & Garg, S. K. (2018). Possible ways to improve postprandial glucose control in type 1 diabetes. *Diabetes Technology and Therapeutics*, *20*, S224-S232. doi: 10.1089/dia.2018.0114

Barbosa, R. R., de Brito-Gomes, J. L., Perrier-Melo, R. J., Costa, M. da C., & Guimarães, F. J. de S. P. (2017). Comparação das alterações cardiovasculares e dos equivalentes metabólicos durante a prática de videogames ativos: Em pé e sentado em cadeiras de rodas. *Revista Brasileira de Prescrição e Fisiologia do Exercício*, *11*(66), 329-335.

Borg, G. (2000). *Escala de Borg para a dor e o esforço percebido. São Paulo: Manole*.

Brinkmann, C., Schäfer, L., Masoud, M., Latsch, J., Lay, D., Bloch, W., & Brixius, K. (2017). Effects of cycling and exergaming on neurotrophic factors in elderly type 2 diabetic men - A preliminary investigation. *Experimental and Clinical Endocrinology and Diabetes*, *125*(7), 436-440. doi: 10.1055/s-0043-103967

de Brito Gomes, J. L., Martins Vancea, D. M., Cappato de Araújo, R., Soltani, P., de Sá Pereira Guimarães, F. J., & da Cunha Costa, M. (2021). Cardiovascular and enjoyment comparisons after active videogame and running in type 1 diabetes patients: A randomized crossover trial. *Games for Health Journal*, *10*(5), 339-346. doi: 10.1089/g4h.2020.0209

de Brito-Gomes, J. L., Barbosa, R. R., & Costa, M. da C. (2020). Glycemic safety of a maximum aerobic test in type 1 diabetics and their correlation with health parameters. *Revista Brasileira de Ciência e Movimento*, *28*(4), 160-168. doi: 10.1016/j.ijcard.2014.10.123

de Brito-Gomes, J. L., Oliveira, L. dos S., Vancea, D. M. M., & Costa, M. da C. (2019). Do 30 minutes of active video games at a moderate-intensity promote glycemic and cardiovascular changes? *Conscientiae Saúde*, *18*(3), 389-401. doi: 10.1590/S1517-86922013000500004

de Brito-Gomes, J. L., Perrier-Melo, R. J., Melo de Oliveira, S. F., de Sá Pereira Guimarães, F. J., & da Cunha Costa, M. (2016). Physical effort, energy expenditure, and motivation in structured and unstructured active video games: A randomized controlled trial. *Human Movement*, *17*(3), 190-198. doi: 10.1515/humo-2016-0021

de Brito-Gomes, J. L., Perrier-Melo, R. J., Oliveira, S. F. M. de, & Costa, M. da C. (2015). Exergames podem ser uma ferramenta para acréscimo de atividade física e melhora do condicionamento físico? *Revista Brasileira de Atividade Física & Saúde*, *20*(3), 232-242. doi: 10.12820/rbafs.v.20n3p232

de Brito-Gomes, J. L., Perrier-Melo, R. J., Wikstrom, E. A., & Da Cunha Costa, M. (2015). Improving aerobic capacity through active videogames: A randomizd controlled trial. *Motriz. Revista de Educacao Fisica*, *21*(3), 305-311. doi: 10.1590/S1980-65742015000300012

de Brito-Gomes, J. L., Santos, M. Mo., Perrier-Melo, R. J., & Costa, M. da C. (2018). A percepção subjetiva de esforço e a frequência cardiaca podem ser suficientes no controle da intensidade do esforço em jogos de video games ativos. *Conscientiae Saúde*, *12*(72), 101–111.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences. In *Statistical Power Analysis for the Behavioral Sciences*. doi: 10.4324/9780203771587

Cohen, J. (1992). A power prime. *Psychological Bulletin*, *112*(1), 155-159. doi: 10.1016/j.jorganchem.2011.01.025

Colberg, S. R., Laan, R., Dassau, E., & Kerr, D. (2015). Physical activity and type 1 diabetes: Time for a rewire? *Journal of Diabetes Science and Technology*, *9*(3), 609-618. doi: 10.1177/1932296814566231

Colberg, S. R., Sigal, R. J., Yardley, J. E., Riddell, M. C., Dunstan, D. W., Dempsey, P. C., Horton, E. S., Castorino, K., & Tate, D. F. (2016). Physical activity/Exercise and diabetes : A position statement of the American Diabetes Association. *Diabetes Care*, *39*(11), 2065-2079. doi: 10.2337/dc16-1728

Delevatti, R. S., Kanitz, A. C., Alberton, C. L., Pantoja, P. D., Marson, E. C., Pinho, C. D. F., Lisboa, S. C., Bregagnol, L. P., & Kruel, L. F. M. (2015). Heart rate deflection point as an alternative method to identify the anaerobic threshold in patients with type 2 diabetes. *Apunts Medicina de l'Esport*, *50*(188), 123-128. doi: 10.1016/j.apunts.2015.05.001

DeSmet, A., Van Ryckeghem, D., Compernolle, S., Baranowski, T., Thompson, D., Crombez, G., Poels, K., Van Lippevelde, W., Bastiaensens, S., Van Cleemput, K., Vandebosch, H., & De Bourdeaudhuij, I. (2014). A meta-analysis of serious digital games for healthy lifestyle promotion. *Preventive Medicine*, *69*, 95-107. doi: 10.1016/j.ypmed.2014.08.026

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175-191.

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., Nieman, D. C., & Swain, D. P. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Medicine and Science in Sports and Exercise*, *43*(7), 1334-1359. doi: 10.1249/MSS.0b013e318213fefb

Garber, C. E., Blissmer, B., Franklin, B. A., Lamonte, M. J., Nieman, D. C., & Swain, D. P. (2011). Quantity and quality of exercise for developing and maintaining neuromotor fitness in apparently healthy adults : Guidance for prescribing exercise. *Medicine & Science in Sports & Exercise*, *43*(7), 1334-1359. doi: 10.1249/MSS.0b013e318213fefb

Hashimoto, S., Noguchi, C. C. Y., & Furutani, E. (2014). Postprandial blood glucose control in type 1 diabetes for carbohydrates with varying glycemic index foods. *36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC 2014)*, 4835-4838. doi: 10.1109/EMBC.2014.6944706

Lau, P. W. C., Liang, Y., Lau, E. Y., Choi, C. R., Kim, C. G., & Shin, M. S. (2015). Evaluating physical and perceptual responses to exergames in chinese children. *International Journal of Environmental Research and Public Health*, *12*(4), 4018-4030. doi: 10.3390/ijerph120404018

Levac, D., Glegg, S., Colquhoun, H., Miller, P., & Noubary, F. (2017). Virtual reality and active videogame-based practice, learning needs, and preferences: A cross-canada survey of physical therapists and occupational therapists. *Games for Health Journal*, *6*(4), 217-228. doi: 10.1089/g4h.2016.0089

Mellecker, R., Lyons, E. J., & Baranowski, T. (2013). Disentangling fun and enjoyment in exergames using an expanded design, play, experience framework: A narrative review. *Games for Health Journal*, *2*(3), 142-149. doi: 10.1089/g4h.2013.0022

Novak, E., & Soyturk, I. (2021). Effects of action video game play on arithmetic performance in adults. *Perception*, *50*(1), 52-68. doi: 10.1177/0301006620984405

Paim da Cruz Carvalho, L., dos Santos Oliveira, L., Boufleur Farinha, J., Socorro Nunes de Souza, S., & Luiz de Brito Gomes, J. (2021). Sex-related glycemic changes after intensity- and duration-matched aerobic and strength exercise sessions in type 1 diabetes: A randomized cross-sectional study. *Journal of Bodywork and Movement Therapies*, *28,* 418-424. doi: 10.1016/j.jbmt.2021.07.028

Pereira, S. V. V. N., Gomes, J. L. de B., Perrier-Melo, R. J., Oliveira, L. dos S., Oliveira, L. I. G. de, & Costa, M. da C. (2017). Acute physiological changes and motivation to exercise boxing: Is the "virtual" boxing feasible? *Revista Brasileira de Ciência e Movimento*, *25*(4), 75-83.

Perrier-Melo, R. J., de Brito-Gomes, J. L., & Costa, M. da C. (2015). A utilização dos videogames ativos no tratamento não farmacológico da diabetes mellitus em idosos: Uma revisão integrativa. *Revista Brasileira de Ciências da Saúde*, *19*(2), 157-162. doi: 10.4034/rbcs.2015.19.02.11

Perrier-Melo, R. J., de Brito-Gomes, J. L., de Oliveira, S. F. M., Guimarães, F. J. de S. P., & Costa, M. da C. (2017). Comparação do gasto calórico e equivalente metabólico duplamente indiretos durante uma sessão com diferentes jogos de videogame ativo. *Revista Brasileira de Prescrição e Fisiologia do Exercicio*, *11*(64), 26-33.

Ramírez-Granizo, I. A., Ubago-Jiménez, J. L., González-Valero, G., Puertas-Molero, P., & Román-Mata, S. S. (2020). The effect of physical activity and the use of active video games: Exergames in children and adolescents: A systematic review. *International Journal of Environmental Research and Public Health*, *17*(12), 1-10. doi: 10.3390/ijerph17124243

Riddell, M., & Perkins, B. A. (2009). Exercise and glucose metabolism in persons with diabetes mellitus: Perspectives on the role for continuous glucose monitoring. *Journal of Diabetes Science and Technology*, *3*(4), 914-923. doi: 10.1177/193229680900300439

Soltani, P., Figueiredo, P., & Vilas-Boas, J. P. (2021). Does exergaming drive future physical activity and sport intentions?. *Journal of Health Psychology*, *26*(12), 2173-2185. doi: 10.1177/1359105320909866

Soltani, P., Figueiredo, P., Ribeiro, J., Fernandes, R. J., & Vilas-Boas, J. P. (2017). Physiological demands of a swimming-based video game: Influence of gender, swimming background, and exergame experience. Scientific Reports, 7(1), 5247. doi: 10.1038/s41598-017-05583-8

Soltani, P., & Salesi, M. (2013). Effects of Exergame and Music on Acute Exercise Responses to Graded Treadmill Running. *Games for Health Journal*, *2*(2), 75-80. doi: 10.1089/g4h.2012.0077

Theng, Y. L., Lee, J. W. Y., Patinadan, P. V., & Foo, S. S. B. (2015). The use of videogames, gamification, and virtual environments in the self-management of diabetes: A systematic review of evidence. *Games for Health Journal*, *4*(5), 352-361. doi: 10.1089/g4h.2014.0114

Yardley, J. E., & Colberg, S. R. (2018). Update on management of type 1 diabetes and type 2 diabetes in athletes. *Methodist DeBakey Cardiovascular Journal*, *14*(4), 273-280. doi: 10.14797/mdcj-14-4-273