Journal Pre-proof

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PII: S1360-8592(23)00180-8

DOI: https://doi.org/10.1016/j.jbmt.2023.05.018

Reference: YJBMT 2647

To appear in: *Journal of Bodywork & Movement Therapies*

Received Date: 11 May 2022

Revised Date: 28 April 2023

Accepted Date: 9 May 2023

Please cite this article as: Luiz de Brito Gomes, J., Soltani, P., Barbosa, R.R., Gomes, José.Adevalton.Feitosa., Costa, M.d.C., Is rating of perceived exertion a valid method for monitoring exergaming intensity in type-1 diabetics? A cross-sectional randomized trial, *Journal of Bodywork & Movement Therapies* (2023), doi: https://doi.org/10.1016/j.jbmt.2023.05.018.

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

Exergames, perceived exertion, and type-1 diabetic patients

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Submission declaration: We confirm that this work is original, has not been published before, and is not currently under consideration for publication elsewhere.

Declarations of interest: None.

Word counts: 3302

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Exertion, Exergames, and type-1 diabetic patients

Abstract

Aims: The rating of perceived exertion (RPE) provides correlations with physiological measurements of exercise intensity, including metabolic equivalent (MET), oxygen consumption ($\dot{V}O2$), 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 whilst 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 *Kinect Adventures!* videogame. METs were measured by a direct gas analyzer during the sessions, and RPE was measured on 6-20 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 [$\dot{V}02$ and HR *vs.* RPE] showed high coefficients ($\dot{V}02$-r = 0.62; average HR-r = 0.62; maximal HR-r = 0.50, $p < 0.05$). However, VS secondary values showed low-moderate coefficients ($\dot{V}02$-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. Health professionals should cautiously use the 6-20 points RPE scale in pathological patients, specifically in T1DM after Exergaming.

Keywords: Perception; Metabolic equivalent; Diabetes mellitus; Physical exercise; Video game; Blood glucose.

Introduction

The exercise guidelines recommend weekly aerobic, anaerobic, or combined activities, in healthy and diabetes mellitus (DM) patients (Colberg et al., 2015). However, several factors including blood glucose changes and lower enjoyment levels hinder DM patients' adherence to exercise (Colberg et al., 2015; Theng et al., 2015). Active video games (exergames) and virtual reality (VR) are the recent exercise trends that can motivate participants (Novak & Soyturk, 2021; Ramírez-Granizo et al., 2020), and might increase their adherence to physical activity (de 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 enhancing cardiovascular and other health-related outcomes (Brinkmann et al., 2017; DeSmet et al., 2014; Perrier-Melo et al., 2015; Masoud & Brinkmann, 2019; de Brito-Gomes et al., 2021).

Unlike type-2 diabetics, severe changes in glycemia (i.e., hypo or hyper) may occur in T1DM patients, and without correct management, the disease can progress through 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, before and after exercise (ADA, 2019; Colberg et al., 2016). Prescribed exercise intensity, whether real or virtual, should be also controlled (ADA, 2019; de Brito-Gomes, Perrier-Melo, Oliveira, et al., 2015; Colberg et al., 2015, 2016; Garber et al., 2011). Traditionally, metabolism assessment, such as metabolic equivalent (MET), was considered as the gold standard methodology for prescribing the exercise intensity and for avoiding complications in T1DM patients (de Brito-Gomes, 2021; Garber et al., 2011). However, this methodology is not a low-cost solution and requires specific training and time to be performed. Therefore, it may not be possible to use such methodology in real-life situations of gyms 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 verify the physical effort in healthy individuals for different exercise modalities (RS and VS), durations (minimum 10 minutes), and intensities (0 - 3 METs: light, 3 - 6 METs: moderate, and > 6.0 METs: vigorous; de Brito-Gomes, Perrier-Melo, Wikstrom, et al., 2015; Lau et al., 2015; Pereira et al., 2017). In diabetic patients, although HR was found to be an important physiological variable for measuring the intensity of exercise (Delevatti et al., 2015), it may not be correlated to the RPE values while exergaming (Brinkmann et al., 2017). In addition, MET and HR may not be a practical way to measure exercise intensity in the real-world environments like care homes and patients' houses. They can also be affected by individual difference, may lack precision and scope, and could be subject to inaccuracies due to the type of equipment used. However, a 6-20 points RPE scale could be used as low-cost instrument and could provide correlations with physiological measurements of aerobic exercise intensity (Borg, 2000; Garber et al, 2011). Therefore, to understand whether RPE could be a better parameter to measure VS intensities, we aimed to examine the concurrent validity of RPE in T1DM patients while exergaming.

Methods

Study type and ethical aspects

This is a cross-sectional design study, and it 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 testing, participants or their legal guardians signed the consent form. All participants were informed and assured by the Declaration of Helsinki protocol.

Inclusion and exclusion criteria and sample size calculation

The inclusion criteria were: (1) not having other comorbid conditions; (2) not using depression medications; and (3) having reasonable and controlled glycated hemoglobin (7.0 - 12.0 %) similar to real-life T1DM conditions. Participants were excluded if: (1) T1DM without regular use of insulin for a minimum of 1.5 years; (2) they did not complete all sessions; (3) if they consumed psychotropic medication or perform exercise therapy during the study; or (4) if they suffer from osteomyoarticular injuries.

A priori sample size calculation was estimated by G*Power 3.1.9 software (Faul et al., 2007), given $\alpha = 0.05$, power $(1-\beta) = 0.9$, and (very) large effect size (ES: 0.8). Therefore, considering two-variable correlation (RPE *vs.* MET values) in two crossover randomized sessions (RS and VS), a minimum of ten participants were needed.

Study design

A randomized, counterbalanced, crossover study was used to establish the concurrent validation protocol. On the first day, baseline data was collected, and participants were familiarized with the equipment (30-minute sitting). After 24 hours and on the second day, cross-over randomization of sessions, blood analysis, and maximal $\dot{V}O_2$peak test were performed. On the third and fourth days, RS and VS sessions with moderate intensity (3 - 6 METs) were randomly performed for 30 minutes.

Recommendations to avoid methodological bias

To avoid methodological bias, we controlled the conditions, before the study and each session. The temperature and relative humidity of the laboratory were set between 22 ± 24°C and 40 ± 60%, respectively. Participants were instructed: (1) to maintain their daily nutrition; (2) to refrain from alcohol, caffeine, or other stimulants for a minimum of 24 hours; (3) to keep their usual hours of sleep and daily activities, excluding their systematic exercises; and (4) to report any factors that could affect their physical or cognitive performance (e.g., injuries and emotional problems).

Procedures and techniques

Day 1 – Baseline data collection and familiarization-resting session

On the first day, basic anamnesis, body composition (using dual-energy X-ray absorptiometry; QDR 4500W, Hologic, USA) and basic anthropometric measurements (weight, height, and BMI) were collected. Before familiarization, participants underwent the scaling and exercise-memory-anchoring instructions to obtain accurate responses in the crossover randomized sessions. The 6-20 Borg RPE scale has 15 numerical categories, verbal and pictorial descriptors, and a scalar representation of various levels of physical exertion. Six to eight points indicate very light effort (e.g., resting or daily activities) and 18 to 20 points indicate near maximum effort (e.g., maximal sprint or the ending of the $\dot{V}O_2$peak test) (Garber et al., 2011). The other points between these two cohort points as light-moderate-vigorous intensities (9 to 11, 12 to 13, and 14 to 17 points, respectively) according to the recommendations (Borg, 2000; Garber et al., 2011). To reduce the risk of bias, a single instructor reported and related the scale numbers and different daily situations to memory-anchoring. The scaling and memory-anchoring instructions were reviewed before the crossover randomized RS and VS sessions to ensure that the participants recalled the feelings experienced. T1DM patients were then instructed to self-report their RPE number as accurately and honestly as possible, and were informed that there were no right or wrong numerical category responses. During familiarization phase, participants sat for 30-minutes in a comfortable chair without conversations, screen time (e.g., TV, smartphones, or physically inactive videogames), and other distractions. They stayed with both feet on the ground and were advised not to sleep but to relax.

Day 2

On the second day, blood samples were taken, and glycated haemoglobin (HbA1C) was measured using semi-automatic cation exchange high-pressure liquid chromatography (CE-HPLC) method. The CE-HPLC is a validated, convenient, and reliable method for Hba1c assessment (Sharma & Das, 2016;

Gupta et al., 2011). After that, participants' $\dot{V}O_2$peak 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 to maximum voluntary fatigue (de Brito-Gomes et al., 2020). The HR and respiratory variables were continuously measured and recorded. The test was discontinued based on the demonstration of at least two of the following criteria: (1) a plateau or decrease in $\dot{V}O_2$ with increasing speed intensity; (2) respiratory exchange coefficient equal to or greater than 1.15; (3) reaching the 95% of maximum HR predicted by age (220 - age) or RPE between 19-20 points. The highest value of $\dot{V}O_2$ found before the interruption of the test was adopted as the $\dot{V}O_2$peak. Finally, the counterbalanced randomization method was performed by allocation using a website randomizer, after which 50% of the volunteers started with the RS and the rest started with VS for each session (ratio 1:1).

Days 3 and 4 – Cross-over randomized sessions

RS session: RS consisted of the treadmill running with 1:1 minute-ratio (40-59% $\dot{V}O_{2peak}$) according to recommendations (Garber et al., 2011). Each matched moderate-intensity (3 - 6 METs) interval was performed for one minute and for a total duration of 30 minutes.

VS session: VS had similar characteristics to RS 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 (de Brito-Gomes, Perrier-Melo, Oliveira, et al., 2015). Three mini-games of River Rush, Rally Ball, and Reflex Ridge were played for 30 minutes (10 minutes each). Similar to the previous study, jumps, squats, and lateral shifts with vertical, and horizontal shoulder extension were performed in all mini-games (de Brito-Gomes, 2021; de 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) effort according to recommendations (Borg, 2000; Pereira et al., 2017; Ramírez-Granizo et al., 2020). The 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?" (de Brito-Gomes et al., 2019). The metabolic analyzer was also 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, and a 30-minute average value was 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 (before and immediately after the session) was checked using a portable glucometer (Accu-check Active, Roche, Brazil; Colberg et al., 2016). The participants performed exercise sessions only if their capillary glycemia ranged from 100 to 250 mg/dL, for which carbohydrates were consumed before the exercise when necessary (100 to 139mg/dL). Otherwise, the exercise session was canceled and repeated within 48-72 hours. After each session, the participants left the room only if their capillary glycemia presented normal values according to recommendations (ADA, 2019). The pre-post Δ% blood glucose was used for comparisons.

Statistical analysis

Physiological data were presented as mean ± SD. Normality of variance were checked using Shapiro-Wilk test and in the case of abnormal distribution, alternative statistics were applied. Primary (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). Level of statistical significance was set to 0.05. Values were also scanned when grouped altogether and in terms of gender to reduce the risk of bias. The effect size (η_p^2) was considered as 0.02 small, 0.13 moderate, 0.26 large for ANOVA RM test (Cohen, 1988). For the RPE validation, separate linear regression analyses were performed for each exercise condition to correlate RPE *vs.* MET values. The concurrent validation was considered as "reached" if the Pearson correlation coefficient (PCC) values were $r \geq 0.50$ (large effect size) according to 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 beginning of the study protocol. The baseline characteristics and secondary values for T1DM patients are presented in Table 1. Before the primary outcome analysis, no sex differences were found in MET and RPE values during any of the sessions (RS, VS, Familiarization) ($p > 0.05$). Then, the participants were grouped.

Table 1. Baseline characteristics and secondary outcomes data from interventions with comparisons for type-1 diabetic 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		
$\dot{V}O_{2\ peak}$ ($ml.kg.min^{-1}$)	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*
Δ Blood glucose pre-post (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; MET values during familiarization were lower than 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 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). On the other hand, no statistical differences were observed between RS and VS sessions ($p > 0.05$). Finally, secondary outcomes were different between RS and VS sessions (maximal HR ($F(2,27) = 55.3$; $p < 0.001$; $\eta_p^2 = 0.86$), average HR ($F(2,27) = 79.1$; $p < 0.001$; $\eta_p^2 = 0.90$), oxygen consumption ($F(2,27) = 63.4$; $p < 0.001$; $\eta_p^2 = 0.87$), and Δ blood glucose pre-post ($F(2,27) = 9.9$; $p < 0.001$; $\eta_p^2 = 0.53$).

When verifying the current 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]; $R^2 = 41$; $p = 0.04$). VS session, however, presented moderate PCC and without statistical significance ($r = 0.42$ [95% IC: -0.3 - 0.8]; $R^2 = 18$; $p = 0.22$; Figure 1).

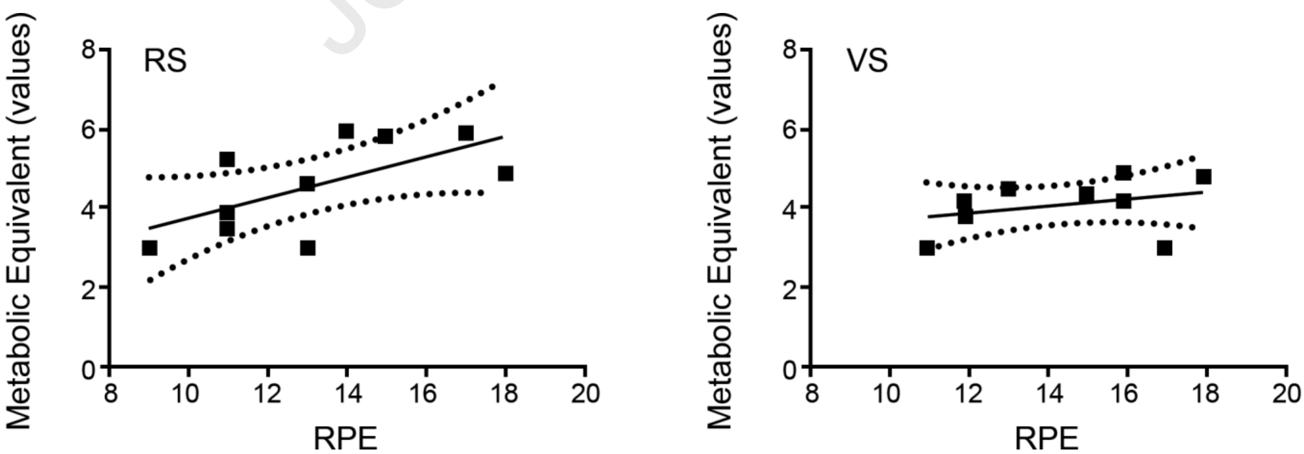

Figure 1. Regression data (RPE *vs.* MET) in RS and VS.
Note 1: RS: $r = 0.64$ [95% IC: 0.2 – 0.9]; $R^2 = 41$; $p = 0.04$ (Large PCC);
Note 2: VS: $r = 0.42$ [95% IC: -0.3 – 0.8]; $R^2 = 18$; $p = 0.22$ (Moderate PCC).

Additional regressions were also made 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). Finally, the PCC value for the 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). Finally, 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 without any statistical significance during the virtual exercise.

RPE vs. METs: Current validation in T1DM patients

We showed that when the intensities and durations of exercise modalities are similar, RPE and MET values had stronger correlations during RS compared to VS session. Therefore, knowledge of RPE in RS would better account for variances in METs in 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; de Brito-Gomes et al., 2016, 2018; Lau et al., 2015; Pereira et al., 2017; Perrier-Melo et al., 2017; Ramírez-Granizo et al., 2020). Several parameters may have contributed to perceptual responses be metabolically less coherent with the expected values. Nature of the game that included video and music and immersive human-computer interaction may have altered players' perception of activity intensity (de Brito-Gomes, 2021; Lau et al., 2015; Soltani & Salesi, 2013). On the other hand, game mechanics consisted of various non-active periods, including waiting for the game to load, watching tutorials, and proceeding to next levels. As a result, patients' total METs were lower than RS where they were continiously running without any iterruption.

RPE vs. other physiological parameters

Unlike previous studies that established correlations between RPE and HR for indirectly estimating METs during different exercise modalities, durations, and intensities (Barbosa et al., 2017; de Brito-Gomes et al., 2016; Pereira et al., 2017; Perrier-Melo et al., 2017), our study showed the correlations between RPE and the secondary outcomes were low or moderate and mostly without any statistical significance. It seems that RPE may not predict changes in HR and oxygen consumption similar to healthy participants during exergames. Within T1DM patients, our results suggested that RPE responses could physiologically explain the changes in HR and $\dot{V}O_2$ for 25-38% in RS and only 4-18% in VS. On the other hand, maximal HR was slightly higher in VS which could be related to the type of activity (e.g., sport, dance, functional training, etc.), time of measurement (e.g., middle or at the end), higher game demands (e.g., upper or lower body muscles) and higher human-computer interaction (de Brito-Gomes et al., 2018). In this study, game mechanics and higher 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 verified that RPE values are strongly correlated with physiological variables in RS for T1DM patients. Therefore, using it in other exercise modalities, such as in virtual sessions, should be done with caution, as they may not reflect true physiological and metabolic exercise intensity. Health professionals who want to use virtual sessions with exergame in their practice, should cautiously use the 6-20 RPE scale in pathological patients, specifically in T1DM.

We would like to note some limitations with the current research. First, a single exergame was used in VS and future studies should explore more games with different types of activities. Second, a single moderate exercise intensity (3 to 6 METs) for both RS and VS was used, and future studies should analyze different intensities (e.g., vigorous intensity of higher than 7 METs). Third, we used 6-20 Borg scale and future studies can explore whether other scales (e.g., 0-10 points Borg scale) could have different correlations with physiological outcomes. Fourth, although male and female patients were not statistically different, future studies should consider gender as a potential moderator for interpreting the results. Finally, those who want to interpret the results clinically should consider which one of correlation or significance matters most to them. As of statistical significance, increasing sample size could change the degree of correlation, and potentially offer different relationship in clinical and practical applications.

Conclusions

The current validation study has shown that 6 to 20 points of the RPE have low-moderate correlations with physiological variables during exergame sessions. Therefore, this scale may not be a valid and strong method 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 (RBPFEX)*, *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. (2021). Cardiovascular and enjoyment comparisons after active videogame and running in type-1 diabetics: Crossover randomized trial. *Games for Health Journal*. doi: 10.1590/S0100-879X2002000600016

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

Gupta, P. K., Kumar, H., Kumar, S., & Jaiprakash, M. (2009). Cation Exchange High Performance Liquid Chromatography for Diagnosis of Haemoglobinopathies. *Medical journal, Armed Forces India*, 65(1), 33–37. https://doi.org/10.1016/S0377-1237(09)80051-8

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

Masoud, M., & Brinkmann, C. (2020). Exergaming for patients with metabolic syndrome?! *Wien Med Wochenschr, 170*(7-8), 171-177. doi: 10.1007/s10354-019-00719-z

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

Sharma, P., & Das, R. (2016). Cation-exchange high-performance liquid chromatography for variant hemoglobins and HbF/A2: What must hematopathologists know about methodology?. *World journal of methodology*, 6(1), 20–24. https://doi.org/10.5662/wjm.v6.i1.20

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

Table 1. Baseline characteristics and secondary outcomes data from interventions with comparisons for type-1 diabetic 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		
Glycated Hemoglobin (%)	8.6 ± 1.4		
Diagnostic Time (Years)	11.5 ± 7.4		
Sex (patients number)	7 male, 3 female		
$\dot{V}O_{2\ peak}$ (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*
Δ Blood glucose pre-post (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.

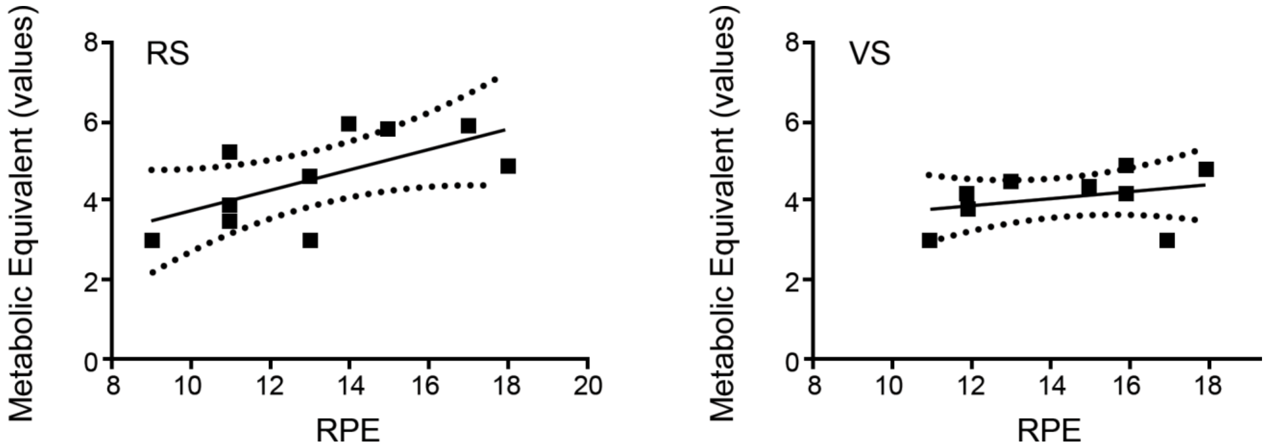

Figure 1. Regression data (RPE *vs.* MET) in RS and VS.

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).

HIGHLIGHTS

- Exergames are the technology that plays a role in perceived exertion in Type-1 diabetic patients.
- Perceived exertion should be studied in Exergames sessions in Type-1 diabetic patients.
- The rates of perceived exertion should be used with caution in Exergame-therapy for Type-1 diabetic patients.
- The 6 to 20 points of Borg scale presented a low-moderate correlation with physiological data in Type-1 diabetic patients

Conflict of interest

None declared.

The authors

2022/05/11