The Effects of Heart Rate Monitoring on Ratings of Perceived Exertion and Attention Allocation in Individuals of Varying Fitness Levels

Robyn Braun-Trocchio*, Ashlynn Williams, Kaitlyn Harrison, Elizabeth Warfield and Jessica Renteria

Sport and Exercise Psychology Lab, Kinesiology Department, Texas Christian University, Fort Worth, TX, United States

There has been a rapid increase in the use of wearable technology-based physical activity trackers. Most of these physical activity trackers include tracking and displaying the individual's heart rate (HR). There is little known about how HR monitoring influences the perception of exertion and attention allocation. Shifting attentional focus toward the body (association), such as monitoring HR, instead of environmental stimuli (dissociation) may increase one's perceived level of exertion. The purpose of the study was to examine the effects of HR monitoring on ratings of perceived exertion (RPE) and attention allocation during an exertive stepping task in individuals of varying fitness levels. The YMCA stepping task normative values determined fitness levels. For the experimental condition, participants were randomly assigned to one of two conditions (i.e., HR monitoring or control) and completed a stepping task with a weighted vest at 20% of their bodyweight. HR, RPE, and attention allocation were collected at 30-s intervals. Performing the stepping task resulted in a gradual increase of HR and RPE along with a shift from dissociative to associative attention across all conditions. Monitoring one’s HR during the task resulted in more dissociative attention allocation, however, no RPE differences were reported between the two conditions. Unfit individuals reported lower levels of RPE during the first time point compared to fit individuals despite having higher HR throughout the task. The results of this study have relevance for applied practitioners implementing physical activity interventions with individuals who monitor their HR.

Keywords: RPE, perceived effort, HR, wearable fitness device, physical activity, exercise psychology

INTRODUCTION

There has been a rapid increase in the use of wearable fitness devices (WFD) with new products released to the consumer market every year. Wearable technology is an electronic device that can be worn on the body (e.g., watch) or on clothing (Wright and Keith, 2014). Most of these physical activity (PA) devices include tracking and displaying the individual’s heart rate (HR) along with other PA data such as acceleration of individual’s movement and calories burned (Bloss, 2017; Nazari et al., 2017). In the United States, the wearable industry was valued at $18 million in 2018 and is expected to reach $64 million by 2023 (Loomba and Khairnar, 2018). More specifically, worldwide wearable device vendors distributed a total of 125.5 million devices, which
is an increase from the 104.3 million units distributed in 2016, making a 20.4% growth (Jia et al., 2018). The majority of research on wearable technology has focused on the accuracy and reliability of these devices (Nazari et al., 2017; Shah et al., 2017; Hernando et al., 2018) as well as promoting PA (Chiauzzi et al., 2015; Jo et al., 2019).

With the continued rise of the obesity epidemic and physical inactivity, WFD are being utilized as behavioral interventions to promote PA. The World Health Organization (2020) recommends 150-min of moderate intensity PA or 75-min of vigorous PA a week to reduce the risk of developing chronic diseases such as cardiovascular disease and type II diabetes. One way to measure the intensity of PA is by measuring an individual’s HR which can be done through a WFD. For moderate intensity PA, the target HR should be between 64 and 76% maximal HR while vigorous intensity is between 77 and 93% maximal HR (Riebe et al., 2018). HR responses to exercise is moderated by knowledge about the suggested intensity and feedback in meeting those levels (Blanchard et al., 1974). HR monitoring has shown to increase overall daily activity and the amount of time in moderate-to-vigorous PA compared to not receiving the HR feedback (McManus et al., 2008).

Another way to measure PA intensity is through Borg’s ratings of perceived exertion (RPE) scale. Perceived exertion during exercise, is a psychophysiological term defined as the subjective intensity of effort, strain, discomfort, and/or fatigue (Noble and Robertson, 1996). Borg (1982) developed a 15-point scale ranging from 6 to 20. These range in ratings from 6 perceiving “no exertion at all” to 20 perceiving a “maximal exertion” of effort. The RPE scale corresponds to the HR range of a normal healthy young male (60–200 beats/min) and HR is predicted by multiplying an individual’s RPE score by 10. However, actual HR can vary depending on age and physical condition. This scale represents a valid and reliable measurement of perceptual effort intensity (Noble and Robertson, 1996). RPE is often used for determining appropriate levels of exercise intensity to define the cardiorespiratory training zone for an individually prescribed exercise regimen. Monitoring RPE levels assists individuals in adjusting their intensity levels. Since there is only a correlational relationship between RPE and HR, more research is needed to determine if HR directly influences perception of effort during increased PA intensity (Hampson et al., 2001). Furthermore, the research between fitness levels and RPE is equivocal. Some research reports that fit individuals report lower RPE values (Hassmen, 1990; Travlos and Marisi, 1996) or no differences (Parfitt et al., 1996; Faulkner and Eston, 2007; Faulkner et al., 2007). More specifically, there is little known about how HR monitoring through a WFD influences an individual’s perception of exertion and attention allocation.

There are two categories of attention allocation, associative strategies which help direct an individual’s focus internally, and toward somatic cues such as attending to breathing, while dissociative strategies direct one’s focus externally such as daydreaming, random, or intentional thoughts (Masters and Ogles, 1998; Scott et al., 1999; Tenenbaum, 2005). According to Tenenbaum’s (2001) effort-related model, individuals tend to shift attention as a function of increased physical workload across all PA settings. As physical workload intensity increases, individuals tend to alternate their attentional focus from a dissociative style to an associative one occurring around an RPE of 13 (“somewhat hard”) (Welch et al., 2007). Research has demonstrated that associative strategies allow for smaller adjustments of effort by monitoring the physiological cues while dissociative strategies divert attention away from the physiological cues thus reducing the perceptions of exertion (Lind et al., 2009; Rose and Parfitt, 2010). Consequently, shifting attentional focus toward the body (association), such as monitoring HR, instead of environmental stimuli (dissociation) may increase one’s perceived level of exertion.

The purpose of the current study was to investigate the effects of HR monitoring on the perception of exertion and attention allocation during an exertive stepping task with individuals of varying fitness levels. The first hypothesis was that individuals in the HR monitoring condition would have higher RPE levels and associative attention allocation compared to the control condition without HR monitoring. The second hypothesis was that unfit individuals would have higher RPE and associative attention allocation compared to fit individuals. Finally, it was hypothesized that unfit individuals with HR monitoring would have the highest RPE and most associative attention allocation.

**MATERIALS AND METHODS**

**Participants**
A total of 66 participants completed the study (females = 47 and males = 19) ranging in age from 18 to 50 (M = 21.97, SD = 6.18). Participants were randomly assigned to either a HR monitoring condition by wearing a wrist watch (n = 35) or a control/no monitoring (n = 31) condition. The General Health and Life Type Questionnaire—Shortened Version (GHLQ; British Columbia Department of Health, 1975) assessed aspects of personal health history. Only participants who did not have any physical or psychological disabilities that would interfere with the completion of an exertive stepping task were included in the study. Using the standardized 3-min YMCA stepping protocol participants were categorized as fit (n = 40) and unfit (n = 26).

**Physical Task**
The stepping task was adapted from the YMCA stepping protocol (Braun and Tenenbaum, 2018). The adapted step task was selected since it is a novel, yet familiar, task to most participants limiting the amount of biases toward the activity, which can influence an individual’s RPE. A similar stepping task has been used to examine VO2 max (Santo and Golding, 2003) and exercise adherence (Glaros and Janelle, 2001). For the actual stepping task, the participants stepped up and down in cadence with a metronome at 96 beats per minute on to the Rogue Resin Plyo Box (height = 30.5 cm). If participants deviated from the pace, researchers promptly corrected them to return to the set cadence. Baseline testing for each participant included completing the standardized YMCA 3-min stepping protocol to determine fitness level. Following a 1-min rest, HR was taken and the recovery HR was compared to the normative
values based on the participant's age and gender (Golding et al., 1989). According to the normative values, fitness levels ranged from very poor to excellent. Fit individuals were categorized as being average or above and unfit individuals were categorized as below average or below. Following the fitness test, the adapted experimental stepping task was completed. First, to manipulate exercise intensity a weighted vest corresponding to 20% of the individual's body weight was added to the participant. Then, each participant completed the experimental task until volitional fatigue or the participant no longer maintained the cadence.

**Instrumentation**

**Demographic Questionnaire**
This questionnaire includes demographic information such as participant's age, gender, and frequency and intensity of regular physical activity.

**Health History Form**
The GHLQ assessed aspects of personal health history including more specific items on coronary and cardiovascular conditions (i.e., heart murmur, irregular heartbeat, and high blood pressure), respiratory (i.e., asthma), and other diseases or ailments (i.e., orthopedic injuries) (British Columbia Department of Health, 1975).

**Task-Specific Motivation Scale**
This questionnaire is designed to examine task-specific self-efficacy (two items based on Bandura’s, 1977, self-efficacy measurement guidelines), task-specific perceived ability, and task-specific motivation (Hutchinson and Tenenbaum, 2007). Participants rated their task-specific self-efficacy, perceived ability, and motivation on a Likert-type scale ranging from 0 (very low) to 10 (very high).

**Commitment Check**
This scale asks participants to report their commitment and effort investment on a 10-point Likert-type scale ranging from 1 (none/not at all) to 10 (very much/very well) at the end of the task. The scale includes three items: (a) ”How hard did you try while you were completing this task?” (b) ”How well do you believe you handled any physical discomfort or pain during the task?” and, (c) ”How much effort did you invest in the task?”.

**Rating of Perceived Exertion**
The RPE scale is a 15-point category-ratio scale ranging from 6 (no exertion at all) to 20 (maximal exertion) measuring perceived exertion during the exercise task (Borg, 1982). The higher the RPE score, the higher the rating of perceived exertion. This scale has high test-retest reliability ($r > 0.83$) and is closely related to various physiological and chemical measurements (Borg, 1982, 1998).

**Attention**
To measure attention allocation during the task, a 10-point scale ranging from 0 (external thoughts, daydreaming, environment, singing songs) to 10 (internal thoughts, how body feels, breathing, muscles) was used (Tammen, 1996). During physical exertion, the one-question scale is an effective and valid measure of attention strategy (Tammen, 1996).

**Apparatus**

**Metronome**
To keep the cadence during the stepping task and maintain the required number of steps, a Steinway and Sons Metronome App from Apple was utilized. The metronome app was set to 96 beats per minute, which elicited 24 completed cycles of stepping or 96-foot strikes per minute.

**Heart Rate Monitor**
HR was measured using Polar's H10 HR monitor system via chest worn sensor strap and a wrist watch HR receiver unit.

**Weighted Vest**
The Rogue Fitness MiR Pro Weighted Vest was utilized to increase the load to 20% of the individuals body weight. The vest was adjusted to fit the participant.

**Procedure**

Preceding any data collection, IRB approval was granted. Participants refrained from physical activity for at least 24 h prior to testing. To reduce possible social facilitation effect, participants were tested individually in a private room. Participants were given an informed consent form outlining the purpose, format, and tasks of the study. Upon agreement to participate in the study, participants completed the demographic, and GHLQ to determine if they were a viable candidate. Only participants who did not have any physical or psychological disabilities that would interfere with the completion of an exertive stepping task were included in the study. All data collection occurred in a single session.

First, participants were randomly assigned to one of the two conditions (i.e., HR monitoring or control). During the experimental task, participants in the HR monitoring condition wore a watch which displayed their HR. In the control condition, the researcher recorded the participant's HR without their knowledge.

Then, participant's height and weight were measured. Next, the researchers attached the Polar HR device to the participant and baseline HR measurements were collected for 3-min. After baseline HR, the RPE and attention scales were explained using a standard script. If the participant was unsure about any of the scales, the researcher offered clarification. Resting attention, RPE and HR were recorded.

Next, the participants were familiarized with the stepper and the metronome and provided with the opportunity to practice the stepping task. Familiarization included the participant taking eight unweighted steps up and down onto the Rogue Resin Plyo Box paced by a metronome at 96 beats per minute while connected to a HR monitor. After participants felt comfortable with the task, the task-specific motivation scale was administered.

Following familiarization, participants completed the 3-min YMCA stepping task to determine the individual's fitness levels. At 30-s intervals throughout the task, participants were asked to verbally state their RPE and attention number and the researcher
recorded their HR without letting the participant know. The HR was taken 1-min post-exercise and the recovery HR was compared to the normative values based on the participant’s age and gender (Golding et al., 1989). Participants were grouped as fit or unfit based on the normative values.

After participant’s HR had returned to resting levels ($M = 337.52\text{-}s$, $SD = 22.71\text{-}s$), the participant was fitted with the weighted vest corresponding to a load of 20% of the participant’s body weight. Baseline RPE, attention, and HR was taken prior to beginning the task. Participants then completed the adapted YMCA stepping task (Braun and Tenenbaum, 2018) with the weighted vest until volitional fatigue or the participant no longer maintained the cadence. RPE and attention, were collected from the participants at 30-s intervals throughout the task. HR was also collected at 30-s intervals. Participants in the HR monitoring condition looked at the watch and verbally stated their HR to the researcher when asked. Participants in this condition were told to only check the HR monitor when requested by the researcher. For the participants in the control condition, the researcher recorded their HR without their knowledge. Upon completion of the task, participants completed a commitment check and were debriefed.

Data Analysis
Multivariate Analysis of Variance (MANOVA) was utilized for the motivation and commitment check items. To test the hypotheses, a repeated measure Analysis of Variance (RM ANOVA) was used for RPE and attention allocation through increments of physical effort expenditure. The two conditions (i.e., HR monitoring and control) and two fitness levels (i.e., fit and unfit) were considered between subject factors and time interval (categorized in 30-s intervals) was considered the within subject repeated factor. When Mauchly’s sphericity reached significance for the main effects ($p < 0.05$) then the Greenhouse-Geisser (GG) epsilon correction coefficient was implemented. Partial eta squared ($\eta^2_p$) was used as a measure of effect size.

RESULTS
Attrition
Descriptive examination indicated high participant attrition rate following the 4th time interval (i.e., 2-min). After this time point, ~11% of participants ceased the stepping task reducing the power of detecting an effect. Thus, the 4th interval was set as the cut-off point in the present analysis.

Task Specific Motivations
To test pre-task differences in motivation between the conditions (HR monitoring) and fitness level (fit and unfit), a MANOVA was conducted. Results revealed a non-significant condition effect, Wilk’s $\lambda = 0.977, F(4,59) = 0.354, p > 0.05, \eta^2_p = 0.023$, non-significant fitness effect, Wilk’s $\lambda = 0.911, F(4,59) = 1.43, p > 0.05, \eta^2_p = 0.089$, and a non-significant interaction effect, Wilk’s $\lambda = 0.967, F(4,59) = 0.504, p > 0.05, \eta^2_p = 0.033$. On average, participants were highly self-efficacious about their ability to perform well ($M = 8.54, SD = 0.23$).

Commitment Check
Results from a MANOVA reported no significant differences among the conditions, Wilk’s $\lambda = 0.877, F(3,60) = 2.80, p > 0.05, \eta^2_p = 0.123$, fitness levels, Wilk’s $\lambda = 0.928, F(3,60) = 1.56, p > 0.05, \eta^2_p = 0.072$, and interaction, Wilk’s $\lambda = 0.987, F(3,60) = 0.26, p > 0.05, \eta^2_p = 0.013$. In general, participants reported high commitment levels to the stepping task ($M = 4.56, SD = 0.26$).

Ratings of Perceived Exertion
A 4 (time intervals) by 2 (conditions) by 2 (fitness) RM ANOVA was conducted for RPE. A significant main effect for time was revealed $GG_{ms} = 289.00, F(1,88,112.55) = 193.20, p < 0.001, \eta^2_p = 0.76$, indicating that as time progressed participants RPE increased in the conditions. A significant time by fitness interaction was found $GG_{ms} = 5.81, F(1,88,112.55) = 3.88, p > 0.05, \eta^2_p = 0.061$. Follow-up t-tests revealed the difference between fitness levels was significant at the 30-s time point, $t_{(64)} = 2.115, p = 0.038$ with fit individuals ($M = 3.90, SD = 2.84$) reporting higher levels of RPE compared to the unfit group ($M = 2.80, SD = 2.41$). Analysis revealed no significant effects for time by condition, $GG_{ms} = 0.446, F(1,88,112.55) = 0.298, p > 0.05, \eta^2_p = 0.005$, or time by condition by fitness, $GG_{ms} = 351, F(1,88,112.55) = 0.235, p > 0.05, \eta^2_p = 0.004$ (see Figure 1).

Attention Allocation
The analysis conducted on attention was similar to the one conducted on RPE. A significant main effect of time was revealed, $GG_{ms} = 77.470, F(1,89,113.55) = 51.55, p < 0.001, \eta^2_p = 0.462$. This suggests that as the task duration increased attention shifted from dissociative to associative. The main effect for condition was not significant, $F(1,60) = 3.42, p = 0.06, \eta^2_p = 0.054$. Non-significant interactions were reported for time by condition, $GG_{ms} = 2.99, F(1,89,113.55) = 0.144, p > 0.05, \eta^2_p = 0.032$, time by fitness, $GG_{ms} = 1.89, F(1,89,113.55) = 0.947, p > 0.05, \eta^2_p = 0.016$, and time by condition by fitness, $GG_{ms} = 0.367, F(1,89,113.55) = 0.244, p > 0.05, \eta^2_p = 0.004$ (see Figure 2).

Heart Rate
The analysis conducted on HR was similar to the one conducted on RPE and attention. A significant main effect of time was revealed, $GG_{ms} = 14524.61, F(1,51,90.64) = 372.55, p < 0.001, \eta^2_p = 0.861$. This suggests that HR increased with time across the conditions and fitness levels. The main effect for fitness was significant, $F(1,60) = 40.73, p < 0.001, \eta^2_p = 0.40$, indicating that unfit participants had higher HR compared to fit participants. There was no significance in time by condition, $GG_{ms} = 29.195, F(1,51,90.64) = 0.749, p > 0.05, \eta^2_p = 0.041$, time by fitness, $GG_{ms} = 104.316, F(1,51,90.64) = 0.2676, p > 0.05, \eta^2_p = 0.043$, or time by condition by fitness, $GG_{ms} = 100.395, F(1,51,90.64) = 2.575, p > 0.05, \eta^2_p = 0.041$ (see Figure 3).

DISCUSSION
With the rapid increase in WFD, which includes HR monitors, more research is needed to examine the effects of HR monitoring on the perception of exertion and attention allocation during an exertive stepping task with individuals of varying fitness.
levels. Contrary to expectations, RPE was not higher for unfit individuals nor the condition with HR monitoring. This aligns with previous research reporting that RPE is not influenced by fitness levels (Parfitt et al., 1996; Faulkner and Eston, 2007; Faulkner et al., 2007). However, other previous research has reported that fit individuals exhibit lower RPE compared to unfit individuals (Hassmen, 1990; Travlos and Marisi, 1996). In the current study, unfit individuals reported significantly lower RPE levels at the 30-s time point compared to fit individuals. This may have occurred because the unfit individuals have less experience with exercise and RPE which could result in inaccurate RPE levels. With abstract concepts, like exertion, adults rely on available contextual information from prior knowledge (Borghi et al., 2011). However, as time progressed RPE increased to similar levels of fit individuals at the 90 and 120-s time points. All participants’ RPE ratings increased linearly with time and effort which is in line with previous research (Hutchinson and Tenenbaum, 2007; Basevitch et al., 2011; Ritchie et al., 2016). No significant difference was reported between the two conditions (e.g., HR monitoring vs. control). HR monitoring does not influence RPE regardless of fitness level. It was hypothesized that HR monitoring would shift attention toward the physiological
cues thus increasing RPE levels, however, this was not supported. This demonstrates that all individuals regardless of fitness level can monitor their HR to guide physical activity training without influencing RPE. HR monitoring allows for intervention designs to track exercise intensity and increase PA (Dooley et al., 2017).

Having knowledge of HR during the task diverted the attention of the participants across both fitness levels, rejecting the hypothesis. These results align with the parallel processing model (Rejeski, 1985) which suggests a limited channel capacity through which information can pass from perceptual field to focal awareness. Therefore, only a limited number of sensory cues may be brought into consciousness at one time. Consequently, both internal and external cues could compete for attention (Pennebaker and Lightner, 1980; Stones, 1980). In the current study, the external stimuli of the HR monitor could have been cognitively appealing for dissociation to occur (Dyrlund and Wininger, 2008). Moreover, it is plausible that the HR monitor provided some distraction which could have allowed the participants to dissociate from the aversive stimuli posed by the stepping task. As the stepping task became more difficult, the participants’ attention become more associative and they may be focusing on the exertive sensations (Hutchinson and Tenenbaum, 2007; Basevitch et al., 2011; Ritchie et al., 2016).

There are several limitations to this study. First, there were unequal numbers of fit and unfit individuals as well as the majority of participants being female. Also, the mean age of participants was ~22 years old. Therefore, future research should have equal number of participants in each fitness level and gender as well as examine younger and older populations. Furthermore, future research should consider more categories for fitness levels. Another limitation is the unequal recovery time between the two tasks. The unfit individuals took longer to return to resting HR levels which could have influenced fatigue during the experimental task. Future research should utilize a standard recover time period. Additionally, only HR was monitored. Other research should include the different aspects of WFD such as accelerometry, steps, and calories burned as well as other WFD devices that are reliable and valid. Results can only be applied to an exertive stepping task in a laboratory setting. Other exercise modalities should be examined to determine if the results are similar in a free-living environment.

The current findings have relevance for applied practitioners implementing PA interventions with individuals who monitor their HR. With the increasing rates of physical inactivity and obesity, it is important to help promote active and healthy lifestyles. WFD are helpful for practitioners and individuals to monitor their PA levels. Self-monitoring is an effective behavioral intervention in that observing one’s own behavior may produce change in the desired direction (Cooper et al., 2007). Monitoring HR has shown to increase overall PA and moderate-to-vigorous PA (McManus et al., 2008). Practitioners can use these WFD for interventions to increase PA and PA intensity. Having an individual monitor their HR at 30-s intervals while performing an exertive task may help dissociate attention while not influencing their exertion levels.

In conclusion, monitoring one’s HR while performing an exertive stepping task diverts attention externally regardless of fitness level. However, no RPE differences were reported between the two conditions. Despite having higher HRs, unfit individuals reported significantly lower levels of RPE during the first time point compared to fit individuals. The results of this study demonstrate that self-monitoring HR can be effective in PA interventions from a psychophysiological perspective.
DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Texas Christian University IRB. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RB-T, AW, and KH: conceptualization. RB-T, AW, KH, EW, and JR: methodology, writing—review, and editing.

REFERENCES

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychol. Rev.* 84, 191–215.

Basevitch, I., Thompson, B., Braun, R., Razon, S., Arsal, G., Tokac, U., et al. (2011). Offaected effects on attention allocation and perception of exertion. *Sport Psychol.* 25, 144–158. doi: 10.1123/tp.25.2.144

Blanchard, E. B., Scott, R. W., Young, L. D., and Edmundson, E. D. (1974). Effect of knowledge of response on the self-control of heart rate. *Psychophysiology* 11, 251–264. doi: 10.1111/j.1469-8886.1974.tb00542.x

Bless, R. (2017). Multi-technology sensors are being developed for medical, manufacturing, personal health and other applications not previously possible with historic single-technology sensors. *Sens. Rev.* 37, 385–389. doi: 10.1108/SR-04-2017-0063

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Med. Sci. Sports Exerc.* 14, 377–381. doi: 10.1249/00005768-198205000-00012

Borg, G. A. (1998). Borg’s Perceived Exertion and Pain Scales. Champaign, IL: Human Kinetics.

Borgi, A. M., Flumini, A., Cimatti, F., Marocco, D., and Scorolli, C. (2011). Manipulating objects and telling words: a study on concrete and abstract words acquisition. *Front. Psychol.* 2:15. doi: 10.3389/fpsyg.2011.00015

Braun, R. A., and Tenenbaum, G. (2018). Perceptions of effort sensations in children at varying stages of cognitive development. *Int. J. Sport Exerc. Psychol.* 18, 639–654. doi: 10.1080/1612197X.2018.1549581

British Columbia Department of Health. (1975). *The Physical Activity Readiness Questionnaire: Validation Report for the 1975 Modified Version.* Vancouver, BC: Ministry of HealthServices. Available Online at: https://vancouver.ca/files/cov/ physical-activity-readiness-questionnaire.pdf

Chiauzzi, E., Rodarte, C., and DasMahapatra, P. (2015). Patient-centered activity monitoring in the self-management of chronic health conditions. *BMC Med.* 13:77. doi: 10.1186/s12116-015-0319-2

Cooper, J. O., Heron, T. E., and Heward, W. L. (2007). *Applied Behavior Analysis, 2nd Edn.* Upper Saddle River, NJ: Pearson.

Dooley, E. E., Golaszewski, N. M., and Bartholomew, J. B. (2015). Estimating accuracy at exercise intensities: a comparative study of self-monitoring heart rate and physical activity wearable devices. *JMIR Mhealth Uhealth* 2:e34. doi: 10.2196/mhealth.7043

Dyrlund, A. K., and Wininger, S. R. (2008). The effects of music preference and exercise intensity on psychological variables. *J. Music Ther.* 45, 114–134. doi: 10.1093/jmt/45.2.114

Faulkner, J., and Eston, R. (2007). Prediction of maximal oxygen uptake from the ratings of perceived exertion and heart rate during a perceptually-regulated sub-maximal exercise test in active and sedentary participants. *Eur. J. Appl. Physiol.* 101, 397–407. doi: 10.1007/s00421-007-0508-6

Glaros, N., and Janelle, C. (2001). Varying mode of cardiovascular exercise in increase adherence. *J. Sport Behav.* 24, 42–62.

Golding, L., Myers, C., and Sinning, W. (1989). *Y’s Way to Physical Fitness.* Champaign, IL: Human Kinetics.

Hampson, D. B., St Clair Gibson, A., Lambert, M. I., and Noakes, T. D. (2001). The influence of sensory cues on the perception of exertion during exercise and central regulation of exercise performance. *Sports Med.* 31, 935–952. doi: 10.2165/00007256-20013130-00004

Hassmen, P. (1990). Perceptual and physiological responses to cycling and running in groups of trained and untrained subjects. *Eur. J. Appl. Physiol. Occup. Physiol.* 60, 445–451. doi: 10.1007/BF00705035

Hernando, D., Roca, S., Sancho, J., Alesanco, A., and Balión, R. (2018). Validation of the apple watch for heart rate variability measurements during relax and mental stress in healthy subjects. *Sensors* 18:2619. doi: 10.3390/s18082619

Hutchinson, J. C., and Tenenbaum, G. (2007). Attention focus during physical effort: the mediating role of task intensity. *Psychol. Sport Exerc.* 8, 233–245. doi: 10.1016/j.psychsport.2006.03.006

Jia, Y., Wang, W., Wen, D., Liang, L., Gao, L., and Lei, J. (2018). Perceived user preferences and usability evaluation of mainstream wearable devices for health monitoring. *PeerJ* 6, e5350. doi: 10.7717/peerj.5350

Jo, A., Cornel, B. D., Coakes, E. C., and Mainous, A. G. (2019). Is there a benefit to patients using wearable devices such as fitbit or health apps on mobiles? A systematic review. *Am. J. Med.* 132, 1394.e1–1400.e1. doi: 10.1016/j.amjmed.2019.06.018

Lind, E., Welch, A. S., and Ekkekakis, P. (2009). Do ‘mind over muscle’ strategies work? *Sports Med.* 39, 743–764. doi: 10.2165/11315120-000000000-00000

Loomba, S., and Khairnar, A. (2018). *Fitness Trackers Market by Device Type (Fitness Bands, Smartwatch and Others), Display Type (Monochrome and Colored), Sales Channel (Online and Offline), and Compatibility (Ios, Android, Windows, Tizen, and Others) – Global Opportunity Analysis and Industry Forecast, 2017–2023.* Allied Market Research. Retrieved from: https://www.alliedmarketresearch.com/fitness-tracker-market (accessed October 11, 2021).

Masters, K. S., and Ogles, B. M. (1998). Associative and dissociative cognitive strategies in exercise and running: 20 years later, what do we know? *Sport Psychol.* 12, 253–270. doi: 10.1123/tp.12.3.253

McManus, A. M., Masters, R. S., Laukkonen, R. M., Yu, C. C., Sit, C. H., and Ling, F. C. (2008). Using heart-rate feedback to increase physical activity in children. *Prev. Med.* 47, 402–408. doi: 10.1016/j.ypmed.2008.06.001

Nazari, S. S., Moradi, A., and Rahmani, K. (2017). A systematic review of the effect of various interventions on reducing fatigue and sleepiness while driving. *Clin. J. Traumatol.* 20, 249–258. doi: 10.1016/j.jctet.2017.03.005

Noble, B. J., and Robertson, R. J. (1996). *Perceived Exertion.* Champaign, IL: Human Kinetics. p. 407.
Parfitt, G., Eston, R., and Connolly, D. (1996). Psychological affect at different ratings of perceived exertion in high- and low-active women: a study using a production protocol. *Percept. Motor Skills* 82, 1035–1042. doi: 10.2466/pms.1996.82.3.1035

Pennebaker, J. W., and Lightner, J. M. (1980). Competition of internal and external information in an exercise setting. *J. Pers. Soc. Psychol.* 39, 165–174. doi: 10.1037/0022-3514.39.1.165

Rejeski, W. J. (1985). Perceived exertion: an active or passive process? *J. Sport Exerc. Psychol.* 7, 371–378. doi: 10.1123/jsp.7.4.371

Riebe, D., Ehrman, J. K., Liguori, G., and Magal, M. (2018). ACSM’s Guidelines for Exercise Testing and Prescription. Philadelphia, PA: Wolters Kluwer.

Ritchie, J., Braun, R., Basevitch, I., Boiangin, N., and Tenenbaum, G. (2016). The effects of lemon taste on attention, perceived exertion, and affect during a stepping task. *Psychol. Sport Exerc.* 25, 9–16. doi: 10.1016/j.psychsport.2016.03.005

Rose, E. A., and Parfitt, G. (2010). Pleasant for some and unpleasant for others: a protocol analysis of the cognitive factors that influence affective responses to exercise. *Int. J. Behav. Nutr. Phys. Act.* 7:15. doi: 10.1186/1479-5868-7-15

Santo, A. S., and Golding, L. A. (2003). Predicting maximum oxygen uptake from a modified 3-minute step test. *Res. Q. Exerc. Sport.* 74, 110–115. doi: 10.1080/02701367.2003.10609070

Scott, L. M., Scott, D., Bedic, S. P., and Dowd, J. (1999). The effect of associative and dissociative strategies on rowing ergometer performance. *Sport Psychol.* 13, 57–68. doi: 10.1123/isp.13.1.57

Shah, Y., Dunn, J., Hubeiner, E., and Landry, S. (2017). Wearables data integration: data-driven modeling to adjust for differences in Jawbone and Fitbit estimations of steps, calories, and resting heart-rate. *Comput. Ind.* 86, 72–81. doi: 10.1016/j.compind.2017.01.003

Stones, M. (1980). Running under conditions of visual input attenuation. *Int. J. Sport Psychol.* 11, 172–179.

Tammen, V. V. (1996). Elite middle- and long-distance runners associative/dissociative coping. *J. Appl. Sport Psychol.* 8, 1–8. doi: 10.1080/10413209608406304

Tenenbaum, G. (2001). "A social-cognitive perspective of perceived exertion and exertion tolerance," in *Handbook of Sport Psychology*, eds R. N. Singer, H. A. Hausenblas, and C. Janelle (New York, NY: Wiley), 810–822.

Tenenbaum, G. (2005). “The study of perceived and sustained effort: concepts, research findings, and future directions,” in *Handbook of Research on Applied Sport Psychology: International Perspectives*, eds D. Hackfort, J. Duda, and R. Lidor (Morgantown, WV: Fitness Information Technology), 335–349.

Travlos, A. K., and Marisi, D. Q. (1996). Perceived exertion during physical exercise among individuals high and low in fitness. *Percept. Mot. Skills* 82, 419–424. doi: 10.2466/pms.1996.82.2.419

Welch, A. S., Hulley, A., Ferguson, C., and Beauchamp, M. R. (2007). Affective responses of inactive women to a maximal incremental exercise test: a test of the dual-mode model. *Psychol. Sport Exerc.* 8, 401–423. doi: 10.1016/j.psychsport.2006.09.002

World Health Organization (2020). *Physical Activity*. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/physical-activity (accessed October 11, 2021).

Wright, R., and Keith, L. (2014). Wearable technology: if the tech fits, wear it. *J. Electron. Resour. Med. Libr.* 11, 204–216. doi: 10.1080/15424065.2014.969051

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Publisher’s Note:** All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

**Copyright © 2022 Braun-Trocchio, Williams, Harrison, Warfield and Renteria. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.**