

Applicability of Ratings of Perceived Exertion as a Measure of Subjective Fatigue in First Responders: An Exploratory Study

Original Research

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Abstract

Introduction: Many researchers use Ratings of Perceived Exertion (RPE) as an indicator of subjective fatigue. Recent findings suggest that energy and fatigue are two distinct unipolar moods.

Methods: Eleven first responders (FR) participated in a 90-minute strenuous exercise battery where they ended the protocol by completing a graded $\text{VO}_{2\text{max}}$ test where they were asked to perform until volitional fatigue, measured through RPE. Subjective feelings of mental energy (ME) and fatigue (MF) and physical energy (PE) and fatigue (PF) were measured before the beginning of the protocol and right after. Data was not normally distributed and presented in median and interquartile ranges. Spearman correlation coefficients were calculated for RPE, post mood state, and changes in mood states.

Results: Participants' self-reported RPE at the conclusion of the $\text{VO}_{2\text{max}}$ test was 18.27 [18.00,19.00]. Post PE ($\rho=-0.012$, $p=0.97$), PF ($\rho=-0.036$, $p=0.92$), ME ($\rho=-0.13$, $p=0.69$), and MF ($\rho=0.43$, $p=0.19$) displayed insignificant correlations with RPE. Similarly, insignificant correlations were observed between changes in PE ($\rho=0.26$, $p=0.44$), PF ($\rho=0.46$, $p=0.15$), ME ($\rho=0.35$, $p=0.30$), MF ($\rho=-0.43$, $p=0.19$), and RPE. Five participants reported an increase in feelings of PE (15.00 [13.00,19.00]) and seven participants reported lower feelings of PF (-12.00 [-19.50,-8.00]) post assessment. Seven participants reported improvements in ME (22.00 [8.00,68.00]) and three reported a reduction in MF (-13.00 [-27.00, -7.00]).

Conclusions: Our findings suggests that self-reported RPE may not be a reliable measure of subjective fatigue in FR populations during acute strenuous exercise. Further our findings support previous work that ME, MF, PE, and PF are four distinct unipolar moods, and researchers seeking to assess fatigue in FR should use RPE with caution as it seems to be a measure of subjective perception of exercise intensity instead of a true measure of subjective fatigue.

Key Words: physical energy, mental energy, mood states

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Introduction

Fatigue is a costly¹ and poorly understood problem that has far-reaching implications, adversely affecting the health and performance of various populations, including military personnel² and first responders.³ In a nationwide survey, 37.9% of 28,902 working adults 18 to 65 years of age in the United States self-reported work-related fatigue, underlining the widespread nature of this issue.¹ Among military and first responder populations, fatigue-related musculoskeletal



injuries have been well-documented, resulting in an estimated loss of 1.6-6 billion dollars.^{4,5} Additionally, work-related fatigue has been reported to cost employers 136.4 billion dollars in lost productivity time.¹ Despite the significance of this issue, there are over 250 different instruments designed to assess fatigue, highlighting the absence of a consensus on the standardized measurement of fatigue.⁶ While some instruments measure fatigue as a lack of energy such as the Fatigue Severity Scale⁷, and Fatigue Assessment Scale⁸, evidence exists that energy and fatigue may be biologically two distinct moods⁹ with their own unique mental and physical components.¹⁰

Mental components of fatigue may include cognitive impairment, difficulty concentrating, and altered mood states, while physical components may involve a reduction in the contractile strength or force production of a muscle and overall feelings of lethargy.¹¹⁻¹³ While, energy, as a separate construct, may have distinct mental components like heightened alertness, improved cognitive function, and positive mood states, coupled with physical components such as increased stamina and vitality.^{9,14} This differentiation is supported by neurobiological studies, which highlight different neural pathways and neurotransmitter systems associated with energy and fatigue.^{12,15} The release of neurotransmitters like dopamine are linked to feelings of energy, while alterations in serotonin and histamine are associated with fatigue.¹² Recognizing these distinct mental and physical components is essential for refining assessment tools and interventions targeted at either energy enhancement or fatigue mitigation. Many of the measures that capture feelings of energy and fatigue¹⁶ are multi-question surveys, which may make them cumbersome in some situations (i.e. during maximal exercise).

To measure fatigue in situations where an instantaneous measure is needed, many researchers have used Ratings of Perceived Exertion (RPE). For example, in a state-of-the-art review of studies that have used wearables to predict fatigue, of the 11 studies that tried to physically fatigue their participants six studies measured fatigue using the Borg RPE scale.¹⁷ Although RPE is used as a measure of subjective perceptions of fatigue, exercise related research suggests that exercising at higher RPE's results in a decline in feelings of fatigue¹⁸, suggesting that RPE may not be a suitable measure of subjective feelings of fatigue. However, a review of the measurement of RPE suggests that RPE is associated with motivation, a psychological construct associated with feelings of energy.¹⁹ With the emergence of recent evidence of the unique biological correlates of energy and fatigue^{9,10}, in this exploratory study these researchers tried to determine whether RPE was a measurement of subjective feelings of energy or fatigue in a tactical population. We hypothesized that self-reported RPE will not have a significant association with subjective feelings of energy or fatigue.

Scientific Methods

Participants

Eleven special weapons and tactics (SWAT) operators (IQR (min, max), (10 male, 1 female, age: 43.00 [38.00,47.00] yrs, years of service: 19.00 [15.00,21.00] yrs, height: 180.00 [175.20,183.00] cm, mass: 88.80 [84.95,96.05] kg) volunteered to participate in this study. To be eligible participants were required to: 1) not have surgery or injury in the last three months; 2) ability to run, perform pull-ups and push-ups without pain; 3) no history of cardiovascular, pulmonary, renal, or metabolic disease and 4) full-time active SWAT operators. All participants were informed of the benefits and risks of the study and signed the informed consent. The study was approved by George Mason University's Institutional Review Board (IRB #:12179B).

Protocol

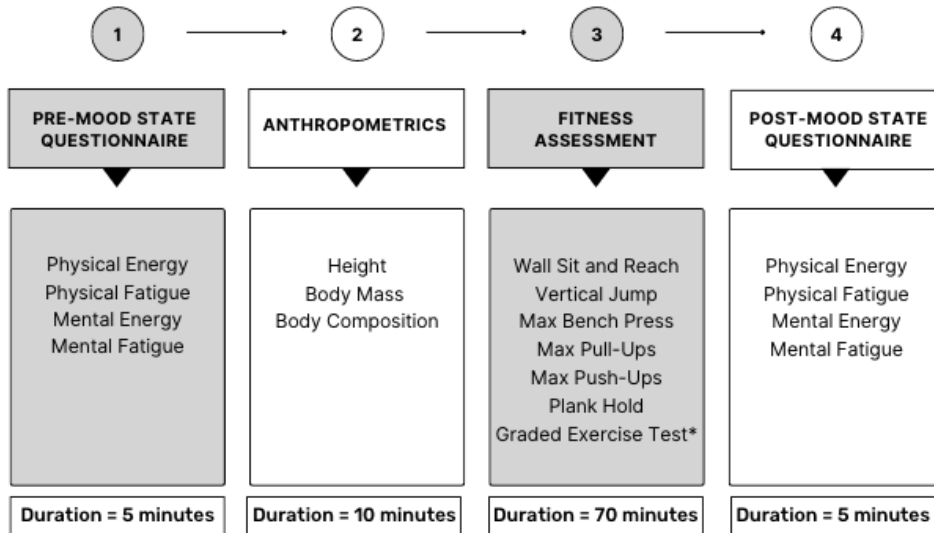
All participants were assessed individually during a single 90-minute session. Participants were instructed to avoid strenuous activity up to 48 hours before testing and avoid food or fluid intake other than water for two hours before assessments. Upon arrival to the testing facility participants completed the informed consent and a state mood questionnaire. Next height, mass, and body composition were measured. The order of the fitness testing was wall sit and reach (WSR), vertical jump (VJ), maximal one-repetition bench press (1RMBP), pull-ups to failure (PULL), push-ups to failure (PUSH), maximal plank hold for time and maximal oxygen consumption test (VO_{2max}). After the completion of the WSR Participants performed a supervised dynamic warm using a standard procedure to minimize skeletal muscle injury during fitness tests. All test sessions were supervised by Certified Strength and Conditioning Specialists.

Questionnaire

Energy and Fatigue: The mental and physical state energy and fatigue scale was used to measure the complexity and changes of mental energy, mental fatigue, physical energy, and physical fatigue. The validity and reliability of these mood state scales have been previously supported by O'Connor.¹⁶ The state scale consists of 12 items, three items per mood measuring their current feelings. Representative statements included "I feel I have energy", and "I have feelings

of being worn out”. The state component was measured on a 0 to 100 Visual Analog Scale (VAS) anchored by “Not at all” (0) to “Highest feeling ever felt” (100). Participants completed mood state questionnaires in a seated position prior to and directly after 90-minutes of strenuous exercise.

Figure 1. Testing Procedures.



*Self-reported rating of perceived exertion

Rating of Perceived Exertion: Self-reported RPE was measured using the Borg 15-point scale. The Borg 15-point scale has been shown to be a valid measure of self-reported physical intensity during various exercise assessments.²⁰ The Borg 15-point scale ranges from 6 to 20, with six representing no effort or very easy and 20 representing extreme effort or difficulty. The structure of the RPE scale was verbally explained to all participants prior to the start of the VO_{2max} test with the use of a visual printout of the scale. Participants were instructed to physically touching the number that they associated with their physical effort on visual printout of the Borg 15-point scale with their index finger. RPE was self-reported in the last 30 seconds of each stage of the VO_{2max} test.

Anthropometric measures

Height and mass were recorded to the nearest 0.01 cm and 0.01 kg using a stadiometer (Detecto, Webb City, MO) and digital floor scale (BOD POD; Cosmed USA, Concord, CA). Body composition was measured using air displacement plethysmography (BOD POD model 2000A; BOD POD, Cosmed USA, Concord, CA) following standardized procedures by the manufacturer. Air displacement plethysmography via the BOD POD has been shown to be a reliable and valid method of assessing body composition.²¹

Fitness Testing

Testing included wall sit and reach, vertical jumps, maximal repetitions pull-ups, maximal repetition push-up, prone plank hold, and a maximal graded exercise test measured participants' VO_{2max} . All test procedures have been previously published by Sax van der Weyden et al.²²

Statistical Analysis

Normality was determined with Shapiro-Wilks tests and visual inspection of histograms. Descriptive statistics, presented as medians and interquartile ranges, were computed for demographic variables, fitness parameters, RPE, and mood states (Table 1). This approach was chosen due to the nonparametric distribution of the data. To determine whether RPE was associated with subjective feelings of energy or fatigue Spearman correlation coefficients were calculated (very weak= 0.00 - 0.19, weak= 0.20 - 0.39, moderate = 0.40 – 0.59, strong= 0.60 – 0.79, very strong= 0.80 – 1.00). Percent change was calculated by subtracting the median post mood state value from the median pre mood state value, then dividing by the median pre mood state value and multiplying by 100. Individual mood state changes

were determined by subtracting pre-self-reported scores from post-self-reported scores (Figure 2). All statistical analyses were performed using R, version 4.0.3 (R Core Team, Vienna, Austria), alpha was set at < 0.05.

Results

The median and interquartile ranges of the completed fitness parameters were: WSR (24.00 [21.00,28.25] cm), VJ (56.89 [52.29,59.69] cm), 1RMBP (113.64 [100.00,123.86] kg), PULL (11.00 [9.50,14.50]), PUSH (45.00 [41.00,49.50]), plank hold (108.50 [91.00,132.25] s), VO_{2max} (42.10 [39.70,45.25]). Participants median self-reported RPE at the completion of the fitness assessment was 18.27 [18.00,19.00], with all participants reporting RPE ≥ 18 at the end of the Wellness-Fitness Initiative treadmill ramp protocol. All fitness parameters were considered average to excellent based on normative data for age and sex.²³

Table 1. Descriptive Data for Demographics, Fitness, and Mood State Variables

Variables	Pre-Median [IQR]	Post-Median [IQR]	Median-Change [IQR]	Percent Change [IQR]
Demographics				
Age	43.00 [38.00,47.00]	-	-	-
Years of Service	19.00 [15.00,21.000]	-	-	-
Height (cm)	180.00 [175.20,183.00]	-	-	-
Mass (kg)	88.80 [84.95,96.05]	-	-	-
Body Fat (%)	20.55 [18.80,23.70]	-	-	-
Fat Free Mass (kg)	72.00 [67.20,77.20]	-	-	-
Fat Mass (kg)	18.40 [15.60,20.60]	-	-	-
Fitness				
WSR (cm)	24.00 [21.00,28.25]	-	-	-
Vertical Jump (cm)	56.89 [52.29,59.69]	-	-	-
1RM BP (kg)	113.64 [100.00,123.86]	-	-	-
Pull up (reps)	11.00 [9.50,14.50]	-	-	-
Push up (reps)	45.00 [41.00,49.50]	-	-	-
Plank Hold (s)	108.50 [91.00,132.25]	-	-	-
VO_{2max} (mL · kg ⁻¹ · min ⁻¹)	42.10 [39.70,45.25]	-	-	-
RPE	18.27 [18.00,19.00]	-	-	-
Mood States				
State PE	163.00 [155.00,222.00]	179.20 [129.50,242.00]	-1.00 [-29.00,14.00]	-0.64 [-14.38,8.34] %
State PF	59.00 [32.50,105.00]	83.00 [43.00,108.00]	-6.00 [-14.00,5.45]	-12.63 [-17.33,3.33] %
State ME	190.00 [171.50,255.00]	214.00 [179.50,260.50]	3.00 [0.00,39.00]	1.19 [0.00,22.19] %
State MF	43.00 [27.50,73.00]	56.00 [25.50,87.00]	3.00 [-0.50,24.50]	6.90 [-5.56,93.44] %

Note: Abbreviations: WSR= Wall sit and reach, 1 RM BP= 1 repetition maximal bench press, RPE= Rating of perceived exertion, PE= Physical energy, PF= Physical fatigue, ME= Mental energy, MF= Mental fatigue.

Spearman correlation coefficients revealed no significant association between self-reported RPE, post mood states, and changes in mood states (Table 2). Post PE ($\rho=-0.012$), PF ($\rho=-0.036$), ME ($\rho=-0.13$), and MF ($\rho=0.43$) revealed insignificant correlations with RPE. Additionally, insignificant correlations were observed between changes in PE ($\rho=0.26$), PF ($\rho=0.46$), ME ($\rho=0.35$), MF ($\rho=-0.43$), and RPE.

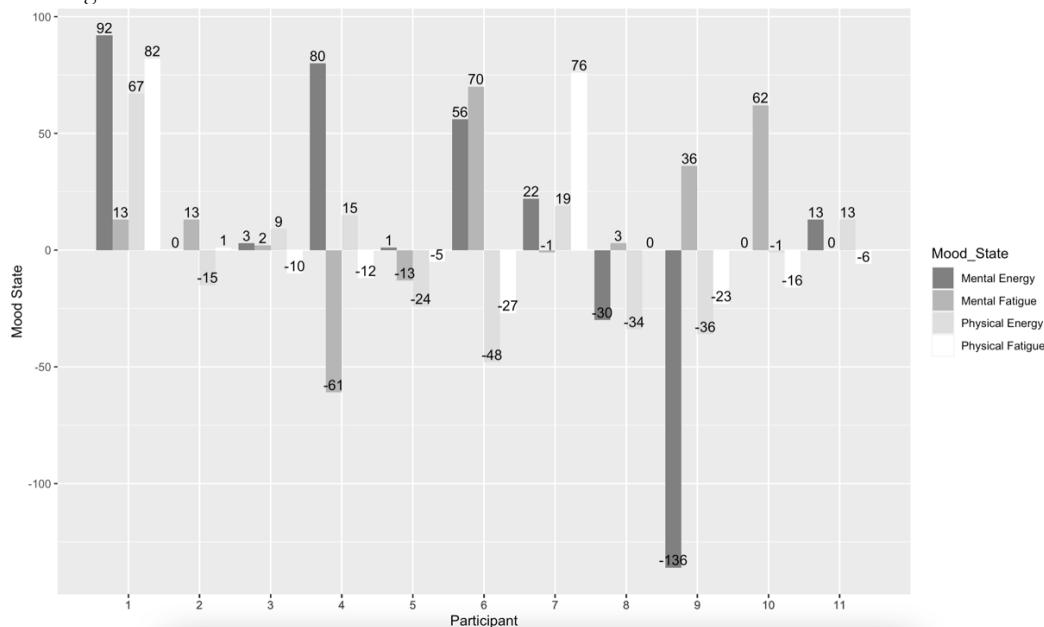
Following the fitness assessment five participants self-reported increases in feelings of physical energy, the median change in feelings of physical energy were -1.00 [-29.00,14.00]. Of the 11 participants, seven reported lower feelings of physical fatigue post assessment, on average the change in feelings of physical fatigue were -6.00 [-14.00,5.45]. Seven participants reported enhancements in mental energy and two participants reported no change, the median change in feelings of mental energy after strenuous exercise were 3.00 [0.00,39.00]. Three participants reported reductions in mental fatigue and one participant reported no change, the median change in feelings of mental fatigue were 3.00 [-0.50,24.50].

Table 2. Correlations of Rating of Perceived Exertion and Mood States

Variable	Spearman Coefficient	p-value
Post State PE	-0.01	0.97
Post State PF	-0.04	0.92
Post State ME	-0.13	0.69
Post State MF	0.43	0.19
Δ State PE	0.26	0.44
Δ State PF	0.46	0.15
Δ State ME	0.35	0.30
Δ State MF	0.43	0.19

Note: Abbreviations: PE= Physical energy, PF= Physical fatigue, ME= Mental energy, MF= Mental fatigue, Δ = change.

Figure 2. Change in Mood States.



Discussion

The objective of this exploratory study was to identify whether fatigue measured using RPE was a measurement of increases in feelings of fatigue or decreases in feelings of energy. The findings of this study suggest that self-reported RPE was not significantly correlated with subjective feelings of energy or fatigue supporting the authors' hypothesis. This suggests that, in a tactical population, RPE may not be a valid measure of subjective feelings of fatigue and/or energy. When examining self-reported interquartile ranges of RPE and changes in mood states, the consistency of self-reported RPE (IQR= 18.00,19.00) was a product of the strenuous exercise battery. Thus, despite all participants self-reporting near maximal exertion the mood states demonstrated considerable variability (PE (-29.00,14.00), PF (-14.00,5.45), ME (0.00,39.00), and MF (-0.50,24.50)). One plausible explanation for this variance in self-reported measures is RPE is typically measured at specific intervals either during an exercise test or throughout a day/week, its ability to measure fatigue accurately and sensitively might be limited. Further, RPE as a construct is an assessment of exertion or a marker of intensity effort²⁴ which is different from what subjective feelings of energy and fatigue measure.⁹

Our findings suggest that RPE protocols that have been used in literature to measure fatigue (exercising until RPE \geq 17), may not assess either feelings of energy or fatigue. For example, Thomas et al. investigated the impact of load carriage during a simulated task in a sample of 12 SWAT operators. They utilized self-reported RPE as an outcome measure for fatigue and concluded there was no significant difference between unloaded and loaded conditions however, there was a significant difference in their fatigue index.²⁵ Similar findings were reported in a scoping review

investigating the use of RPE as a measure of fatigue to assess changes in postural control. The authors reported there was no significant correlations between self-reported RPE and changes in postural control following fatiguing conditions.²⁶ These findings are contradictory to those published by Mahoney and colleagues who suggest that feelings of fatigue are associated with balance control.²⁷ Taken together the findings of Thomas et al.²⁵ and Jo et al.²⁶ support the findings of the current study suggesting RPE is not an accurate or sensitive measure of fatigue. Although the original intent of the Borg RPE scale was to measure perceived exertion and fatigue²⁸, a study in rugby players suggests that RPE may be a measure of exercise intensity, instead of fatigue.²⁹ While the notion RPE as a measure of exercise intensity is accepted by sports scientist largely due to its non-invasive nature and cost-effectiveness our findings suggest that RPE should not be used as an assessment of fatigue. Session-RPE, better known as the Foster's³⁰ method utilizes self-reported RPE and the duration of a training session to quantify exercise intensity and may not assess session-fatigue.³¹

In the present study, RPE did not measure either energy or fatigue mood state as some participants reported declines in feelings of fatigue and/or increases in feelings of energy. Interestingly, one participant reported an increase in all mood states, two reported an increase in both physical energy and fatigue, two reported an increase in mental energy and fatigue, while two reported a decrease in both physical energy and fatigue. Further, because several participants reported an increase in both feelings of energy and fatigue, our findings support previous work that finds unique biological correlates of feelings of energy and fatigue. This study highlights the need to assess mental and physical energy and fatigue as four separate constructs.^{9,10}

Limitations

This study is not without limitations. The first limitation to this study is the small sample size. Further, due to the homogeneity of the population, these findings cannot be extrapolated in other populations. Future studies in more diverse populations using different protocols are warranted. Lastly, it is not possible to determine if alterations in mood states are directly related to fatigue induced from the fitness assessment or hormonal changes. The work of Loy and O'Connor reports that acute exercise leads to the release of brain dopamine, serotonin, and histamines that been shown to influence feelings of fatigue and energy post-exercise.³²

Conclusions

The objective of this study was to identify whether RPE measured subjective feelings of energy and/or fatigue. The findings of this study suggest that RPE is not a measure of mood state and instead it measures subjective perceptions of exercise intensity in a group of tactical athletes. These findings suggest the limitations of using RPE as a measurement of fatigue in this population. Future researchers interested in single item scales to measure fatigue in a tactical population should consider other scales that may be better at identifying subjective feelings of energy and fatigue.

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