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Research article

Validation of Polar Grit X Pro for Estimating Energy Expenditure during Military Field Training: A Pilot Study

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Abstract

Wearables are lightweight, portable technology devices that are traditionally used to monitor physical activity and workload as well as basic physiological parameters such as heart rate. However recent advances in monitors have enabled better algorithms for estimation of caloric expenditure from heart rate for use in weight loss as well as sport performance. can be used for estimating energy expenditure and nutritional demand. Recently, the military has adopted the use of personal wearables for utilization in field studies for ecological validity of training. With popularity of use, the need for validation of these devices for caloric estimates is needed to assist in work-rest cycles. Thus the purpose of this effort was to evaluate the Polar Grit X for energy expenditure (EE) for use in military training exercises. Polar Grit X Pro watches were worn by active-duty elite male operators (N = 16; age: 31.7 ± 5.0 years, height: 180.1 ± 6.2 cm, weight: 91.7 ± 9.4 kg). Metrics were measured against indirect calorimetry of a metabolic cart and heart rate via a Polar heart rate monitor chest strap while exercising on a treadmill. Participants each performed five 10-minute bouts of running at a self-selected speed and incline to maintain a heart rate within one of five heart rate zones, as ordered and defined by Polar. Polar Grit X Pro watch had a good to excellent interrater reliability to indirect calorimetry at estimating energy expenditure (ICC = 0.8, 95% CI = 0.61 - 0.89, F (74,17.3) = 11.76, p < 0.0001) and a fair to good interrater reliability in estimating macronutrient partitioning (ICC = 0.49, 95% CI = 0.3 - 0.65, F (74,74.54) = 2.98, p < 0.0001). There is a strong relationship between energy expenditure as estimated from the Polar Grit X Pro and measured through indirect calorimetry. The Polar Grit X Pro watch is a suitable tool for estimating energy expenditure in free-living participants in a field setting and at a range of exercise intensities.

Key words: Wearable, calories, military, exercise.

Introduction

Wearables are lightweight, portable technology devices that have become an integral part of providing detailed analysis of personal analytics, physical status, and physiological parameters for everyday fitness enthusiasts, elite performers, medical professionals, and researchers (Gordt et al., 2018; Lynch et al., 2019; Strain et al., 2020). Bioengineering advances in noninvasive sensor technologies have made these devices increasingly popular and enticing to users of all kinds (Li et al., 2016; Vigneshvar et al., 2016), including military personnel to quantify their physical workload (Friedl, 2018). Warfighters are under high stress from strenuous physical training, operational demands, lack of sleep, and inadequate nutrition (Szivak and Kraemer, 2015). While it is known that physical exercise leads to physiological adaptations, its impact on an individual's recovery and performance is not typically measured in military populations (Hellsten and Nyberg, 2015; Kraemer and Ratamess, 2005). Due to human fluctuation in physical development and recovery, nutritional needs between individuals varies (Kraemer and Szivak, 2012). Wearable devices can be used for individualized energy expenditure and nutritional demand estimation, autoregulation of physical readiness, guidance for optimal performance and recovery, and feedback (Hajj-Boutros et al., 2023; Seshadri et al., 2019).

A popular feature of wearables is the estimation of energy expenditure (EE). Within EE, some wearables claim to estimate macronutrient partitioning during exercise (Center, 2020); and the most popular wearables [Garmin, Fitbit, and Apple] have demonstrated significant error in estimating total energy expenditure (TEE). TEE is the total number of calories burned throughout one day to include caloric expenditure to maintain life as well as all activity (Bai et al., 2016; O'Driscoll et al., 2020). Although most wearables companies do not state the algorithm used to calculate EE, it is speculated that many use heart rate (HR), age, height, and weight (Dooley et al., 2017). Currently, portable devices for measuring energy expenditure via volume of oxygen consumption (VO2) are cumbersome to the participant, expensive, and not always practical for data collections with larger populations. Thus, the use of wrist-based wearables could provide an alternate means for energy expenditure estimates during field military training exercises and with larger cohorts.

Multiple studies have validated a variety of wearables for use in research (Chevance et al., 2022; Chinoy et al., 2021; Chinoy et al., 2022; Evenson et al., 2015; Hajj-Boutros et al., 2023). While these studies have included an assortment of wearables, the Polar® Grit X Pro (Polar International, Kempele, Finland) wrist wearable has not been validated in any study to date. Polar is known for HR technology and the accuracy of its HR monitors (wrist and chest) (Goodie, 2000; Shumate et al., 2021). Polar wrist-based HR technology has been validated in multiple studies (Düking et al., 2020; O'Driscoll et al., 2020), and its ability to measure HR with photoplethysmography is excellent, with strong correlation (r = 0.99) to chest strap (Düking et al., 2020). Accuracy of HR measurement is

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critical in determining exercise or activity intensity, which dictates EE (Medicine, 2006).

The Polar Grit X Pro was designed with military personnel in mind, with such features as a ruggedized screen, extended battery life, Global Positioning System (GPS), navigation, water resistance to 100 meters, altimeter, and over 100 activities by which to quantify workload and estimate energy expenditure. While the Polar technology is similar across devices, prior to use in field research, it is critical to validate metrics within the desired subject population for accuracy or acceptable margin of error. Due to its rugged design, battery life, and historical HR accuracy, the Polar Grit X Pro wearable was chosen for assessment for use in military field estimates of energy expenditure. Therefore, the purpose of this study was to validate energy expenditure estimates provided by the Polar Grit X Pro watch against indirect calorimetry prior to use during military field training.

Methods

Participants were briefed on the premise of the study and provided an opportunity to volunteer. To participate in the study, all volunteers provided written informed consent. Following consent, participants were asked to give body composition via a dual-energy X-ray absorptiometry (DEXA) scan. Participants were then scheduled to complete the treadmill test at a later day and instructed to physically rest the day prior.

Participants

Participants consisted of active-duty elite male operators (N = 16; age: 31.7 ± 5.0 years, height: 180.1 ± 6.2 cm, weight: 91.7 ± 9.4 kg). Participants were required to be active-duty military service members. Due to the low percentage of female operators, none of our participants were female. Participants were excluded from the study if they sustained an injury that prevented them from being able to complete running on a treadmill. Data collection occurred during a global health pandemic (COVID-19) where regulations and precautions were followed per local and federal protocols which limited total sample size. In addition, participant availability, unpredictable changes in training schedules and a small military unit played a role in the reliance on convenience sampling for this study rather than traditional a priori sample size calculations. The study protocol was approved by the Naval Health Research Center Institutional Review Board (NHRC.2020.0004) and adhered to Department of the Navy human research protection policies.

Body composition

Participants completed all testing at their home duty station. Body composition and anthropometric measurements were obtained via dual-energy X-ray absorptiometry (DEXA) (GE HealthCare, Chicago, IL, USA) and Seca 874 bodyweight scale and stadiometer (Seca, Hamburg, Germany).

Measures

Body composition was maintained via DEXA scan, a low-level x-ray medical imaging test. Participants were asked to lie in supine position for approximately 15 minutes while the x-ray machine measured bone density, body fat and muscle mass of the whole body.

The Polar Grit X Pro wearable device measured HR with photoplethysmography, the use of infrared light to evaluate blood flow near the surface of the skin, while worn on the participant's wrist. The heart rate data is also used by Polar to estimate energy sources used.

Exercise protocol

Participants were asked to refrain from exercise the day prior to testing. Participants arrived at the exercise laboratory and were fitted for a face mask (COSMED, Rome, Italy) for metabolic testing, a Polar HR monitor chest strap utilized in other validation studies (Hermand et al., 2019), and a Polar Grit X Pro watch (worn on their nondominant wrist). The Polar Grit X Pro was programmed to "running (treadmill)" activity mode and was initiated in synchronization with the metabolic cart at the onset of the treadmill testing. After a self-selected treadmill warm-up, participants each performed five 10-minute bouts of running on a treadmill at a self-selected speed and incline to maintain a HR within one of five HR zones, as ordered and defined by Polar. The HR zones remained in order from lowest to highest, and all 10-minute bouts were completed in succession with no rest in between. Treadmill speed was adjusted so that HR would decrease or increase accordingly until the participant was in the appropriate HR zone. Once a stable HR within the desired zone was achieved, the 10 minutes started. On average, it took 2 minutes for HRs to adjust to the new speed/zone. Each stage was 10 minutes to be able to adjust treadmill speed and incline to allow participant to achieve steady state in the desired heart rate zone and have adequate gas collection time for data recording. The five HR zones were as follows:

Zone 1: 50 - 59% of HR max
Zone 2: 60 - 69% of HR max
Zone 3: 70 - 79% of HR max
Zone 4: 80 - 89% of HR max
Zone 5: 90 - 100% of HR max

While exercising, continuous metabolic measurements (30-second averaging) were obtained via indirect calorimetry using a COSMED metabolic cart, which served as the criterion method.

Data were synchronized to the metabolic cart and downloaded to the Polar Flow software in accordance with the manufacturer's recommendations. Data were exported from Polar Flow via a Microsoft Excel file for statistical analysis.

Statistical analysis

Prior to all formal hypothesis testing data was explored for normality and any potentially influential outliers, with outcomes of preliminary exploration presented in the results section. To quantify the reliability of energy expenditure estimates provided by the Polar Grit X Pro watch against indirect calorimetry, an intraclass correlation coefficient (ICC) was used. All ICC estimates, their 95% confidence intervals, as well as formal hypothesis tests were calculated using R (Version 4.2; R Foundation for Statistical Computing; Vienna, Austria). For assessing the significance of device reliability, *F* tests were carried out with an alpha level set at $p < 0.05$. Following the widely accepted guidelines for selecting and reporting ICCs(Koo and Li, 2016), the appropriate model, type, and definition of the analysis were determined based on our research questions. To investigate the absolute agreement of the two methods in estimating the target metrics via Polar Grit X Pro and COSMED metabolic cart, a 2-way mixed effects ICC with a single rater type was calculated for each individual metric across and within all exercise intensities with reliability estimates interpreted as poor for an ICC of less than .4; fair as an ICC between .4 - .59; good as an ICC between .6 - .74; and excellent as an ICC between .75 - 1.0. Furthermore, descriptive statistics were calculated for all demographic body composition metrics.

Results

Data from both devices were examined for outlier cases as defined by any value falling more than three standard deviations from the mean. Based on this set cutoff, no influential outliers were identified, and all data points were retained in the analysis. Prior to the calculation of ICC estimates and omnibus tests, distributions in energy expenditure estimates as well as macronutrient partitions were explored and yielded no significant departures from normality. Participant demographics are presented in Table 1.

Table 1. Participant demographics

	Mean ± SD	Range
Age, years	31.7 ± 5.0	16.0
BF%	21.5 ± 6.0	24.1
BMI, kg/m^2	28.3 ± 3.0	9.2
Weight, kg	91.7 ± 9.4	30.5
Height, cm	180.1 ± 6.2	22.9
Lean mass, kg	69.0 ± 6.1	19.1
FFM, kg	72.6 ± 6.5	20.0

BF, body fat; BMI, body mass index; FFM, fat-free mass; SD, standard deviation. * Demographic data represent (n = 16) for all variables except VO2 peak (n = 15).

Physiological data

Data were analyzed separately within each of the five HR zones as well as aggregated across all HR zones and energy expenditure estimates. Means, standard deviations (SDs), and ICC summary statistics are reported in Table 2.

Aggregated data

Aggregated HR zone data indicated that the Polar Grit X Pro watch had good to excellent interrater reliability compared with indirect calorimetry (metabolic cart) at estimating energy expenditure (ICC = 0.8, 95% confidence interval [CI] = 0.61 - 0.89), F (74,17.3) = 11.76, $p < 0.0001$.In macronutrient partitioning, there was fair to good interrater reliability in estimating percent fat (%FAT) and carbohydrate (%CHO) (ICC = 0.49, 95% CI = 0.3 - 0.65), F (74,74.54) = 2.98, $p < .0001$, between the Polar Grit X Pro and the metabolic cart, independent of HR zone (Figure 1).

Table 2. Energy expenditure and macronutrient composition by heart rate zone.

	Polar Grit X Pro (Mean ± SD)	Metabolic cart (Mean ± SD)	ICC	ICC Interpretation	95% CI	F	p
Exercise intensities combined							
n	75	75					
Calories	122 ± 36	111 ± 32	0.80	Excellent	0.61-0.89	11.76	<0.001***
%FAT	39 ± 23	35 ± 18	0.49	Fair	0.30-0.65	2.98	<0.001***
%CHO	61 ± 23	65 ± 18	0.49	Fair	0.30-0.65	2.98	<0.001***
Zone 1 (50-59% HRmax)							
n	16	16					
Calories	75 ± 9	69 ± 12	0.15	Poor	-0.30-0.58	1.39	0.259
%FAT	69 ± 4	53 ± 21	0.04	Poor	-0.24-0.41	1.11	0.415
%CHO	31 ± 4	47 ± 21	0.04	Poor	-0.24-0.41	1.11	0.415
Zone 2 (60-69% HRmax)							
n	16	16					
Calories	103 ± 16	96 ± 18	0.58	Fair	0.16-0.83	4.33	0.005**
%FAT	54 ± 8	35 ± 17	0.14	Poor	-0.12-0.49	1.79	0.185
%CHO	46 ± 8	65 ± 17	0.14	Poor	-0.12-0.49	1.79	0.185
Zone 3 (70-79% HRmax)							
n	16	16					
Calories	129 ± 19	120 ± 15	0.26	Poor	-0.19-0.65	1.79	0.129
%FAT	36 ± 12	30 ± 13	0.15	Poor	-0.31-0.58	1.39	0.260
%CHO	64 ± 12	70 ± 13	0.15	Poor	-0.31-0.58	1.39	0.260
Zone 4 (80-89% HRmax)							
n	14	14					
Calories	150 ± 16	135 ± 15	0.09	Poor	-0.25-0.51	1.28	0.328
%FAT	21 ± 10	29 ± 14	0.28	Poor	-0.16-0.67	2.01	0.112
%CHO	80 ± 10	71 ± 14	0.28	Poor	-0.16-0.67	2.01	0.112
Zone 5 (90-100% HRmax)							
n	13	13					
Calories	166 ± 17	146 ± 17	0.07	Poor	-0.23-0.48	1.24	0.354
%FAT	7 ± 5	25 ± 13	0.09	Poor	-0.10-0.42	1.68	0.238
%CHO	93 ± 5	75 ± 13	0.09	Poor	-0.10-0.42	1.68	0.238

%CHO, present calories from carbohydrate; CI, confidence interval; %FAT, percent calories from fat; ICC, intraclass correlation coefficient; SD, standard deviation. ** p < 0.01, *** p < 0.001

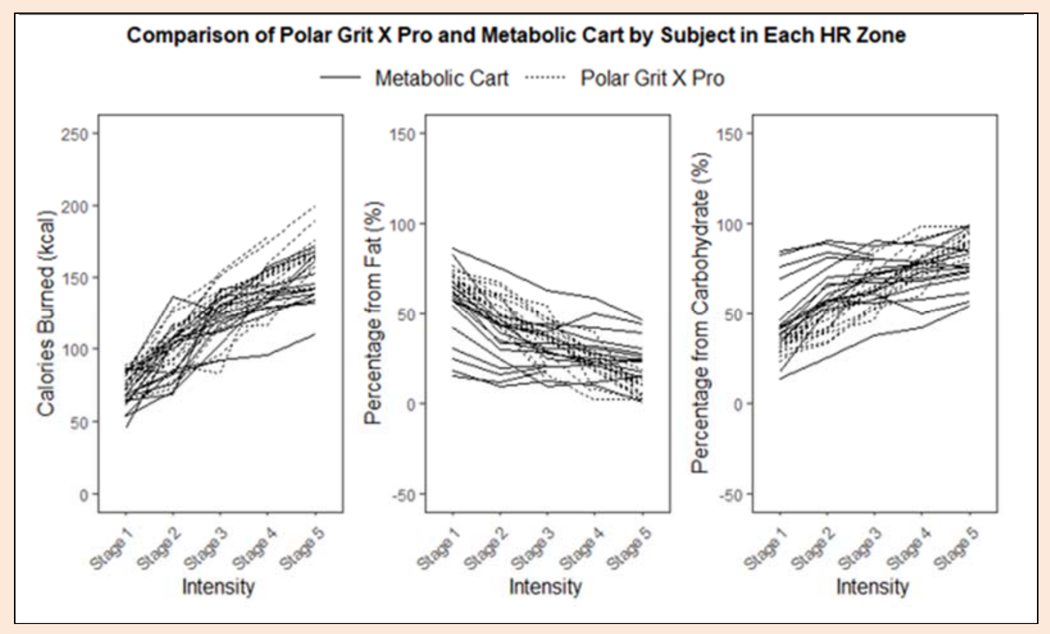

Figure 1. Comparison of energy expenditure and macronutrient partitioning via Polar Grit X Pro and metabolic cart by participant in each heart rate zone, stages 1 - 5. The Polar Grit X Pro watch had good to excellent reliability compared with the metabolic cart at estimating energy expenditure (intraclass correlation [ICC] = 0.8) and had fair to good reliability in estimating percent fat and percent carbohydrate breakdown (ICC = 0.49).

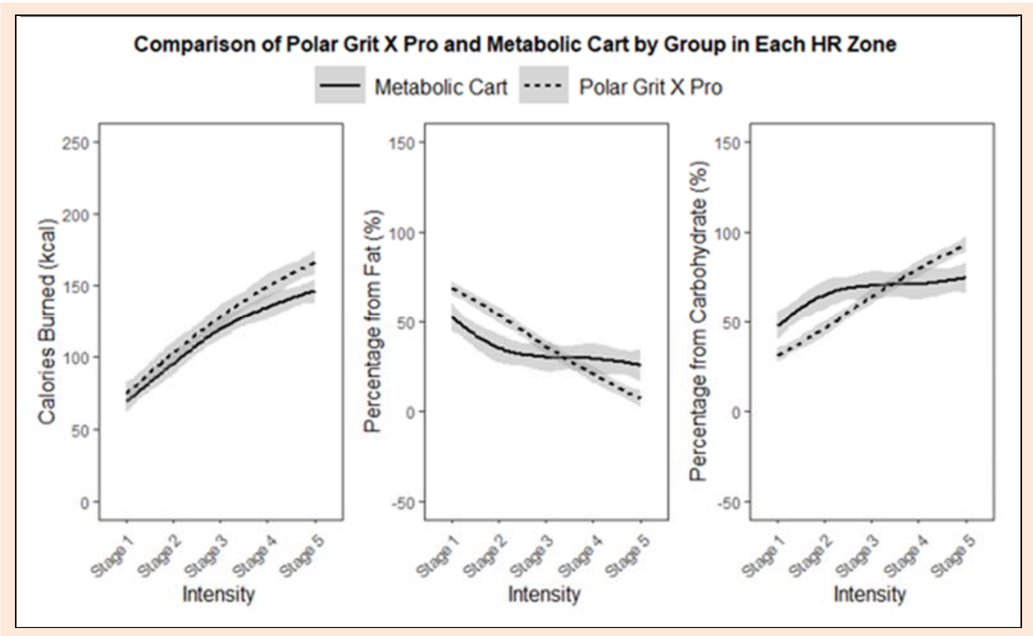

Figure 2. Comparison of energy expenditure and macronutrient partitioning via Polar Grit X Pro and metabolic cart by group in each heart rate (HR) zone, stages 1 - 5. The Polar Grit X Pro watch had good to excellent reliability compared with the metabolic cart at estimating energy expenditure combined across all HR zones, but it underestimated percent fat and overestimated percent carbohydrate at higher intensities.

Individual HR zone data

Separated by individual HR zone, energy expenditure reported on the Polar Grit X Pro watch had poor interrater reliability compared with the metabolic cart in zones 1, 3. 4, and 5 (zone 1: ICC = 0.15, zone 3: ICC = 0.26, zone 4: ICC = 0.09, zone 5: ICC = 0.07) and fair reliability in zone 2 (ICC = 0.58, 95% CI = 0.16 - 0.83), F (15,13.76) = 4.33, p = .005. In macronutrient partitioning, interrater reliability in estimating %FAT and %CHO was poor to none across each respective HR zone (zone 1: ICC = 0.04, zone 2: ICC = 0.14, zone 3: ICC = 0.15, zone 4: ICC = 0.28, zone 5: ICC = 0.09).

In examining the relationships between the two devices within each HR zone, both devices produced a similar trend line in energy expenditure as well as macronutrient partitioning. Both devices exhibited a steady increase in energy expenditure and %CHO as exercise intensity increased paired with a proportional decrease in %FAT (Figure 2). Despite the general similarities in trend, there was an intersection between zones 3 and 4 where the Polar Grit

X Pro and metabolic cart exhibited an inversion in macronutrient partitioning estimates with the Polar Grit X Pro underestimating %FAT (mean = 20.5, SD = 10.24) and overestimating %CHO (mean = 79.5, SD = 10.24) in zone 4 compared with %FAT (mean = 29.13, SD = 13.59) and %CHO (mean = 70.87, SD = 13.59) estimated by the metabolic cart. As indicated by the fair ICC determination for energy expenditure in zone 2, there was a strong correlation between the Polar Grit X Pro watch and the metabolic cart, whereas zones 1, 3, 4, and 5 showed weaker correlations (Figure 3).

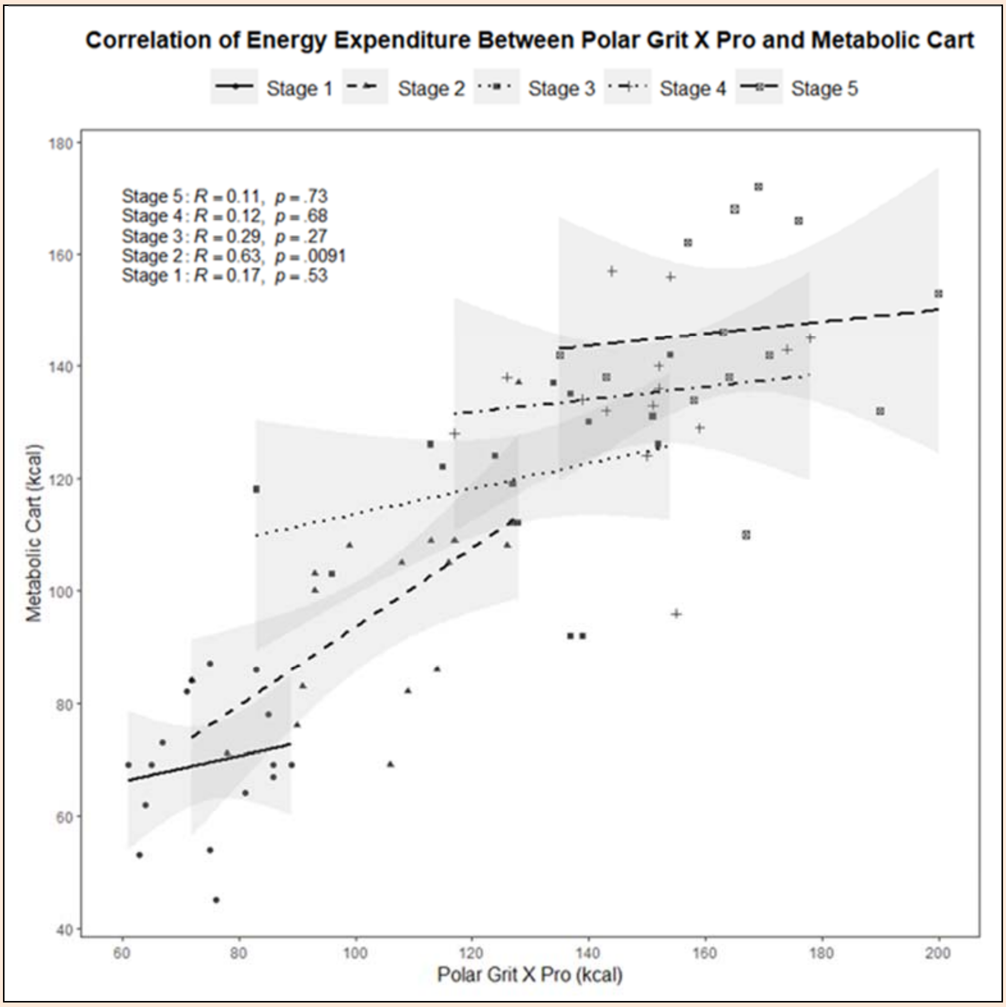

Figure 3. Correlation of energy expenditure via Polar Grit X Pro and metabolic cart in each heart rate (HR) zone, stages 1 - 5. When separated by HR zone, energy expenditure reported on the Polar Grit X Pro watch had negligible reliability compared with the metabolic cart in zones 1, 3, 4, and 5 (zone 1: intraclass correlation [ICC] = 0.15, zone 3: ICC = 0.26, zone 4: ICC = 0.09, zone 5: ICC = 0.07) and fair reliability in zone 2 (ICC = 0.58). Pearson's *R* values provided for ease of interpretation.

Discussion

The purpose of this study was to validate EE estimates provided by the Polar Grit X Pro watch against indirect calorimetry prior to use during military field training. The main finding is that there is a strong relationship between estimated EE by the Polar Grit X Pro and caloric measurement via indirect calorimetry. There was a moderate correlation between estimated %FAT and %CHO use by the Polar Grit X Pro and substrate utilization data as measured by indirect calorimetry; however, these estimates should be used cautiously and/or in context with other data such as dietary intake records or recall. There was fair interrater reliability between the Polar Grit X Pro and metabolic cart for energy expenditure in HR zone 2 (60 - 69% HR max), while zones 1, 3, 4, and 5 (50 - 59%, 70 - 79%, 80 - 89%, and 90 - 100% HR max, respectively) had poor reliability. Collectively, the data presented herein suggest that the Polar Grit X Pro is sufficient for estimating overall energy expenditure during exercise training with variable intensities across the activity and is suitable for use with free-living participants.

Our findings are similar to other studies with a high accuracy of EE estimation in wrist-based wearables in lab settings (Rumo et al., 2011) and in free-living conditions (Siddall et al., 2019; White et al., 2019) in comparison to indirect calorimetry and doubly labeled water. With similar purpose, the UK military used wearable devices to monitor participant's physiological responses to challenging environmental conditions (Smith et al., 2023). These similarities in findings are rooted in the understanding that the use of heart rate is integral for determining exercise intensity, and thus energy expenditure (Medicine, 2006).

Wearable devices are a noninvasive, lightweight, durable, and convenient way to collect valuable metrics for both daily training and prolonged field operations. Practically speaking, for military training or for sport, EE over the course of a day as well as during specific training bouts is useful to help determine energy balance for performance and recovery (Blair et al., 2015), and estimates of energy expenditure can be useful to military operators and tactical athletes for nutritional planning and training loads. Thus, reasonable accuracy is necessary. The primary goal of this study was to validate the Polar Grit X Pro watch for use in a military field setting for EE over time during unconventional (military) training, with a secondary aim of determining accuracy of estimates of macronutrient use. Recently, with the increased popularity of wearables and the desire to use wearables on free-living participants, multiple studies have looked at the validity of these wearables and accuracy in estimating EE (Goodie, 2000; Hall et al., 2004; Kinnunen et al., 2019; Li et al., 2016; O'Driscoll et al., 2020). Collectively, these studies have demonstrated that commercial devices underestimate energy expenditure and that devices that utilize HR in combination with an activity are more accurate than devices that do not (Kinnunen et al., 2019; O'Driscoll et al., 2020). Heart rate explained 85% of the variation in energy expenditure and thus, is a critical component for improvement of accuracy of wrist-based devices for measurement of EE (Kinnunen et al., 2019).

The most significant variables in total energy expenditure are activity level and exercise. In this study, we used the running activity across various intensities to validate the energy expenditure that is reflective of daily living. It is assumed that throughout the day, most individuals engage in activities that vary from light to vigorous. This is most reflective of the military training environment, which is dynamic in nature and varies in intensity. As such, our data show that aggregated data over various intensities demonstrate a strong correlation between the Polar Grit X Pro and indirect calorimetry. This agrees with other studies that found short exercise bouts (5 minutes) did not correlate well to indirect calorimetry, but averaged intensities across the entire validating activity had a strong correlation (r = 0.88) (Düking et al., 2020). Further, it has been suggested that using activity-specific prediction equations has higher validity than not selecting a specific activity profile (O'Driscoll et al., 2020). Therefore, how the wearable monitor is used to collect energy expenditure data is important when using in a free living or field environment. Moreover, understanding the context in which the data are used is critical. When using EE to improve sport or military performance and training loads, a 15 - 20% (~100 kcal) margin of error is trivial, and thus acceptable, unlike the use of EE in a clinical weight loss study (Düking et al., 2020; Kinnunen et al., 2019; O'Driscoll et al., 2020).

Another Polar Grit X Pro feature explored was the ability to estimate macronutrient use during exercise. Substrate use, measured via respiratory exchange ratio (which indicates a value of 0.7 as predominant fat oxidation and a value of 1.0 and above as predominant carbohydrate oxidation), decreases with exercise duration, age, dietary fat intake, and carbohydrate intake before and during exercise (Rothschild et al., 2022). During a bout of maximum effort exercise, the metabolism uses predominantly lipid oxidation while below 40% of VO2 max and then switches to predominantly carbohydrate oxidation as intensities increase (Bergman and Brooks, 1999). In endurance-trained individuals, the metabolism downshifts carbohydrate oxidation in place of lipid oxidation at submaximal steady-state exercise to increase efficiency (Holloszy and Coyle, 1984). The Polar Grit X Pro poorly estimated %FAT and %CHO when broken down by zones. These estimates are based on exercise intensity (HR) and known sex differences in substrate utilization. Substrate oxidation during exercise is determined by exercise intensity and duration as well as individual differences in oxidative capacity, which is influenced by training status, body composition, age, and diet (Alghannam et al., 2021; Jeukendrup and Wallis, 2005; Rothschild et al., 2022). Therefore, individuals should not rely on these data for fueling needs or for macronutrient consumption planning.

The main strength of this study is the relevance of having a valid wrist-based wearable to estimate EE for use in field data collection in military populations. This will enable untethered [indirect calorimetry] and non-burdensome [portable indirect calorimetry] data collections especially in large populations and when in extreme environments. While other devices have been validated, the Polar Grit X Pro has the metrics and durability most suitable for the military population. Further, this study compared multiple exercise intensities which captured a range of heart rate zones. This is critical in that during an average day, heart rate changes depending upon active time and type of activity (e.g., activities of daily living such as walking versus exercise-based activities); and thus, provides a degree of accuracy and confidence in EE depending upon what heart rate zone an individual is in.

Limitations

There are a several limitations to this study that need to be addressed. The primary limitation is that the population was male active-duty elite military members, no female personnel were included. Second, the time in each HR zone was 10 minutes, which is in line with other validations studies that tested each HR zone for 5 - 10 minutes (Düking et al., 2020; Kinnunen et al., 2019) but is likely not long enough to fully evaluate substrate partitioning during exercise. Lastly, only the running activity was evaluated in this study. This activity was chosen to accommodate a wide range of HRs, with the assumption that military training activities involve a variety of HR intensities. Despite these limitations, the participants in this study represented a range of ages and body compositions.

Conclusion

The Polar Grit X Pro watch is acceptable to use for estimating daily energy expenditure during activities performed across a range of intensities and is practical for use in the field. While overall energy expenditure was comparable to the metabolic cart, the Polar Grit X Pro watch did not accurately estimate macronutrient composition. The advancement of wearables enables the quantification of military training activities with larger cohorts that previously were unattainable due to time, difficulty due to environment (e.g., remote locations, difficult terrain) too extreme for equipment (e.g., portable VO2 monitors), or too expensive (e.g., double-label water). While not without limitations, the use of wrist-based monitors expands research capabilities and provides individual feedback to the user for self-regulation. Of great importance, data from wearables used to monitor and gather information over time can be used to improve performance. From a research and an individual perspective, aggregation of wearable data allows for patterns and trends to be recognized for development of interventions, performance enhancement tools and risk mitigation strategies. However, understanding the estimation limitations as well as the context in which the wearable is used is critical.

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Key points

- Validation of Polar Grit X Pro watch to quantify energy expenditure during field training exercises in military personnel.
- Strong relationship between energy expenditure in Polar Grit X Pro and indirect calorimetry
- Moderate correlation between estimated %FAT and %CHO use by the Polar Grit X Pro and substrate utilization data as measured by indirect calorimetry.
- Aggregation of wearable data allows for patterns and trends to be recognized for development of interventions, performance enhancement tools and risk mitigation strategies.

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