THE ACCURACY OF POLAR "OWNCAL" IN ESTIMATING
ENERGY EXPENDITURE DURING AEROBIC
DANCE BENCH STEPPING

THESIS

Presented to the Graduate Council of
Texas State University–San Marcos
in Partial Fulfillment
of the Requirements

for the Degree

Master of EDUCATION

by

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San Marcos, Texas
December, 2008

ACKNOWLEDGEMENTS

First of all, thank you God for giving me the strength and determination that I needed. Next, thank you to my finance, who has supported me and has given me encouragement throughout this entire process.

I would also like to thank my Mom and my Dad. Even though you were not in the same town during this process, I felt like you were by my side through it all. Without your constant encouragement and positive outlook I would have not been able to make it through the end.

Thank you to all the student interns, and lab staff who were there to help me throughout my entire data collection process. There was no way I could have done all of that without you guys!

Finally, I would like to thank my committee members. Dr. Pope and Dr. McCurdy, thank you for coming on board so quickly and working hard to help me through this fast turn around. Dr. Lloyd, thank you for all of your patience and positive attitude during our meetings. You are truly responsible for where I am today. I truly appreciate all of your hard work and dedication.

This manuscript was submitted on November 13, 2008.

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This study examined the accuracy of the Polar F6 heart rate monitor (HRM) in estimating energy expenditure (EE) using one's predicted maximal oxygen consumption (VO_{2max}) and maximal heart rate (HR_{max}) (PHRM), and also to determine if the use of one's actual measured VO_{2max} and HR_{max} (AHRM) improves the accuracy during aerobic dance bench stepping (ADBS) in females. Thirty-two females (age 18-25) of average fitness level followed a 20-minute ADBS routine while wearing both PHRM and AHRM.

When compared to indirect calorimerty (IC), the PHRM and AHRM significantly overestimated EE by 28% (2.4 kcal min^{-1}) and 27% (2.0 kcal min^{-1}), respectively. There were no significant differences between the PHRM and AHRM. In conclusion, the Polar F6 is inaccurate in estimating EE during ADBS for college-age females.

CHAPTER 1

THE ACCURACY OF THE POLAR "OWNCAL" IN ESTIMATING ENERGY EXPENDITURE DURING AEROBIC DANCE BENCH STEPPING

For successful and sustainable weight loss and weight maintenance both energy intake (EI) and energy expenditure (EE) should be considered (USDA, 1996; USDHHS, 2005). With regard to weight maintenance, EE and EI should consistently be in balance, whereas for weight loss, EE should consistently exceed EI (McArdle, Katch, and Katch, 2007). Strategies for controlling EI and increasing EE are integral to achieving the appropriate energy balance (i.e., EE = EI or EE > EI). For example, EE involves three components (i.e., resting metabolism, the thermic effect of feeding, and physical activity), though physical activity is the most integral in raising EE. Thus, monitoring EE during exercise is one of many possible strategies that should be considered when trying to achieve a desired balance between EE and EI.

Measuring heart rate (HR) during exercise is a common technique employed for monitoring exercise intensity and, if needed, modifying exercise intensity.

Furthermore, because of its relatively linear relationship with oxygen consumption, HR can be used to estimate EE (Ceesay et al., 1989; Christensen, Frey, Foenstelien, Aadland, & Refusion, 1983; Spurr et al., 1988). Specifically, EE estimation equations have been developed that estimate EE from HR and a combination of factors that may include: gender (Hiilloskorpi et al., 1999; Hiilloskorpi, Pasanen, Fogelholm, Laukkanen, & Manttari, 2003; Keytel et al., 2005; Rennie, Hennings, Mitchell, & Wareham, 2001), weight (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003; Keytel et al., 2005; Reenie et al., 2001), age (Keytel et al., 2005; Reenie et al., 2001), maximal oxygen consumption (VO_{2max}), (Keytel et al., 2005), and sitting HR (Reenie et al., 2001). For example, Keytel et al. (2005) developed a prediction equation for EE from exercise HR, gender, weight, VO_{2max}, and age on a sample of 115 men and women of varying age (18 to 45) and fitness level (27 to 81 $ml\,kg^{-1}\,min^{-1}$). The correlation coefficient (r) between the measured and estimated EE was 0.913, with the model accountıng for 83.3% (R^2) of the variance in EE.

With advances in technology, heart rate monitors (HRMs) have been developed that measure HR and estimate EE. Polar Electro, Inc., is one of the main distributors of HRMs. Polar developed "OwnCal," a software system that estimates EE from the user's exercise HR and personal data, including age, gender, height, weight, maximal oxygen consumption (VO_{2max}), and maximal HR (HR_{max}) (Polar Electro Oy, 2004a). In most settings, the user's true VO_{2max} and HR_{max} are impractical to obtain. Thus, Polar also developed software to estimate VO_{2max} and HR_{max} from the user's personal data. Research, however, is limited regarding the accuracy of estimating EE with Polar monitors equipped with the "OwnCal" system. Crouter et al. (2004), for instance, suggested that the Polar S410 HR monitor, which is equipped with the "OwnCal" software and the option of either predicting VO_{2max} and HR_{max} or entering in the actual VO_{2max} and HR_{max}, yielded varied estimates of EE during exercise on a treadmill, cycle ergometer, and rowing ergometer. Specifically, for males, the use of actual and predicted values (i.e., VO_{2max} and HR_{max}) resulted in a reasonable mean error of 4% (SD $\pm$ 10%) and 2% (SD $\pm$18), respectively. For females, however, the use of actual and predicted values resulted in a larger mean error of 12% (SD $\pm$ 13%) and 33% (SD $\pm$ 21), respectively. While the use of actual values in predicting EE shows promise, the results reported by Crouter et al. are limited by the sample size and have not been further substantiated. Moreover, since the mode of exercise employed was limited to treadmill exercise, cycling, and rowing, the results cannot be generalized to other modes of exercise.

Aerobic dance bench stepping (ADBS) is a popular activity that, when monitored properly, can help increase daily EE. A HRM worn during ADBS may assist participants in achieving an appropriate energy balance for weight management. However, to our knowledge, no published studies have examined the accuracy of any brand of HRM in estimating EE during ADBS. Thus, the purposes of this study were: 1) to examine the accuracy of the Polar F6 for estimating EE in a sample of women during ADBS using one's predicted VO_{2max} and HR_{max}, and 2) to determine whether the use of measured VO_{2max} and HR_{max} improves the accuracy of the Polar F6 for estimating EE. Based on previous research (Crouter et al., 2004), we hypothesize that the Polar F6 will overestimate EE in our sample of women during ADBS.

Methods

Participants

Thirty-two adult females (mean age = 20.34 years of age; range of 18 to 25 years), enrolled in aerobic classes at a university, volunteered to participate in this study. The mean body weight of the participants was 61.2 kg with a range of 44.8 to 85.9 kg; while the mean height was 164.3 cm with a range of 152.4 to 175.3 cm tall (see Table 1). To ensure that the participants were able to follow a videotaped ADBS routine and also to reduce the risk of injury, the criteria for participant participation included a minimum of one month of regular attendance (at least 2 days per week) in formal group exercise classes. Additional inclusion criteria included absence of contraindications to exercise testing.

Based on VO_{2max} measurements, the aerobic fitness levels of the participants ranged from well below average to well above average (Whaley, Brubaker, & Otto, 2006). Therefore, these results can likely be generalized to women of varying fitness levels who are familiar with the techniques required for ADBS. This investigation was approved by the university's Institutional Review Board. Lastly, written informed consent was obtained from the participants after a detailed description of all testing procedures was provided.

Testing Procedures

Participants visited the laboratory on two separate occasions, 2 to 7 days apart. Prior to their first visit, participants were provided the following pre-test instructions based on the

ACSM guidelines (ACSM, 2006): 1) refrain from food, alcohol, caffeine, and tobacco 3 hours before testing, 2) drink plenty of fluids in the 24 hours before testing, 3) get the recommended 6-8 hours of sleep on the night prior to each testing day, and 4) refrain from strenuous exercise 24 hours prior to testing.

During visit 1, participants: 1) signed a consent form, 2) completed a comprehensive health appraisal, 3) were measured for height and weight (in light exercise clothing, without shoes) using a calibrated physician's scale (Detecto Scale Co., Jerico, New York), and 4) performed a Bruce graded maximal exercise test (ACSM, 2006) on a trackmaster treadmill (FullVision, Newton, KS). The highest full-minute VO_2 observed during the final stage of the test was accepted as VO_{2max} if two of the following criteria are met: 1) achievement of age-predicted HR_{max} (i.e., 220 – age), 2) a respiratory-exchange ratio (RER) greater than 1.15, and 3) VO_2 plateau (less than a 150 ml min^{-1} increase between stages) (Howley, Bassett, & Welch, 1995). During maximal and submaximal exercise tests, each participant's HR was measured with a Polar F6 telemetric HRM (Stanford, CT). HR was recorded at the end of each minute. Expired air was analyzed throughout all tests with a PARVO Medics metabolic analyzer (Salt Lake City, UT). Oxygen Consumption (VO_2), carbon dioxide production (VCO_2), minute ventilation (V_E), Respiratory Exchange Ratio (RER), and Rate of Energy Expenditure (REE) were determined from 60-s averages. Calibration was performed before each test using a certified gas mixture (O_2 = 16% and CO_2 = 4%, Scott Medical Products, Plumsteadville, PA). Rating of Perceived Exertion was recorded at the end of each minute according to the Borg 6-20 point scale (Borg, G.A., 1982).

During visit 2, user data (i.e., age, height, weight, gender, resting/sitting HR, VO_{2max}, and HR_{max}) was first entered into two Polar F6 HRMs. Resting/sitting HR was measured while participants sat for five minutes, with the lowest HR being recorded. One watch was programmed with the participant's actual VO_{2max} and HR_{max}, which herein is referred to as the actual heart rate monitor (AHRM). The participant's actual VO_{2max} and HR_{max} were determined during visit 1. The other watch was programmed with the participant's predicted VO_{2max} and HR_{max}, which herein is referred to as the predicted heart rate monitor (PHRM). The predictions of VO_{2max} and HR_{max} were performed according to the manufacturer's recommendations outlined in the Polar F6 user's manual (Polar Electro Oy, 2004a). The Polar F6 uses a non-exercise prediction equation based on the participant data. Once programmed, the HRMs were affixed to the participants' chest. Damp sponges were placed between the chest and the HRM to ensure that HR was recorded throughout the entire testing session. Participants were also fitted with a headgear that housed the breathing apparatus. Participants were then instructed to follow the exact movements of a 20-minute ADBS routine.

The primary investigator, a group exercise leader (Aerobics and Fitness Association of America-certified) with 4 years of ADBS teaching experience, had previously developed and videotaped the choreographed bench stepping routine of moderate to hard intensity consisting of movements commonly used in ADBS (Pyror, E., & Kraines, M.G., 1999). The routine consisted of basic stepping, alternating kicks, knee lifts, leg curls, back leg lifts, turn stepping, and traveling back and forth over the top of the bench. Various arm movements, including opening and closing the arms overhead and across the chest, and lateral and forward raises to shoulder height, were performed simultaneously with the stepping. The cadence of 126 beats min^{-1} was verified by a metronome.

Before beginning the ABDS routine, the 6-in bench was positioned so that the participant could perform the routine. The gas collection tubing was suspended overhead and to the side of each participant, extending from the metabolic cart through a plastic loop support. With the continuous aid of a technician to control the slack in the tubing, the ABDS routine was completed with minimal interference in movement from the metabolic apparatus.

When the participant was ready, the video was started and the participant began exercising. The ADBS video lasted 20-minute and was performed using a 6-inch bench at a cadence of 126 beats min^{-1}. However, to ensure that steady-state data was used for data analysis, the HRM and metabolic cart did not start recording the physiological data until minute-6 of the exercise routine. Thus, the physiological measurements (i.e., VO_2, VCO_2, V_E, RER, REE, and HR) for minutes 6 through 20 were used for data analysis. The averages are shown in Table 2. Based on the average $\%VO_2R$, the exercise intensity of the ADBS routine was considered to be moderate (Pollock et al., 1998).

Statistical Analysis

Between-participants statistical tests were conducted with bivariate correlation and multiple regression. Three dependent variables (EE-IC, EE-AHRM, and EE-PHRM) were regressed on several demographic and actual tests, or predicted tests, where appropriate. In examining differences within participants, one-way repeated measures ANOVA was used to compare EE values (kcal min^{-1}) for PHRM, AHRM, and IC. Post hoc paired comparisons were then performed using Bonferroni corrections to an alpha of 0.05 as tests of statistically significant differences.

Results

Between-participants Tests

Pearson product moment correlations between variables were calculated and are reported in Table 3. Significant bivariate correlations were found with weight: and height ($r = 0.36$, $p < 0.05$), predicted VO_{2max} ($r = -0.82$, $p < 0.001$), EE as estimated by PHRM ($r = 0.63$, $p < .001$), EE as estimated by AHRM ($r = 0.76$, $p < 0.001$), and EE as measured by IC ($r = 0.80$, $p < 0.001$). Other significant correlations were between predicted VO_{2max} and: EE-PHRM ($r = -0.61$, $p < .001$), actual VO_{2max} ($r = 0.38$, $p < 0.05$), EE-AHRM ($r = -0.67$, $p < 0.001$), EE-IC ($r = -0.65$, $p < 0.001$). Significant correlations were found between EE-PHRM with: actual sitting HR ($r = 0.52$, $p < 0.01$), actual VO_{2max} ($r = -0.74$, $p < 0.001$), actual HR_{max} ($r = 0.51$, $p < 0.01$), EE-HRM ($r = 0.82$, $p < 0.001$), and EE-IC ($r = 0.69$, $p < 0.001$). Actual sitting HR was correlated with actual VO_{2max} ($r = -0.57$, $p < 0.01$) and with actual HR_{max} ($r = 0.38$, $p < 0.05$). Lastly, EE-AHRM was correlated with EE-IC ($r = 0.85$, $p < 0.001$). Interestingly, EE-AHRM and EE-PHRM were less than perfectly correlated with EE-IC, only one demographic characteristic (i.e., weight) was significantly related to EE-IC, and only one of the predicted values from the HRM (i.e., predicted VO_{2max}) was significantly related to EE-IC.

In order that the variance explained by one variable while controlling for the impact of other variables could be ascertained, two different multiple regressions were used to examine the impact of two sets of predictors for the criterion of EE-IC. In the regression model with actual HRM data predicting EE-IC, the F-score was 7.99 ($p < 0.001$). The six predictors of height, weight, age, actual sitting HR, actual VO_{2max}, and actual HR_{max} (measured during the exercise test) explained 66% of the variance in EE-IC. Only the beta weight associated with weight was statistically significant ($\beta = 0.83$, $p < 0.001$). None of the other predictors were significantly related to the criterion of EE-IC (see Table 4).

In the second regression model, IC-EE was regressed on the same demographic variables as well as the values predicted by the HRM (predicted VO_{2max} and predicted HR_{max}). Predicted sitting HR_{max} was not included since it was a constant. The model showed an F-score of 12.69 ($df1 = 4$, $df2 = 27$; $p < 0.001$). However, age and predicted HR_{max} were perfectly collinear ($r = 1.0$), so the former was kicked out of the model. Although 65% of the variance in the criterion was explained by these remaining predictors, none of the beta weights were significantly related to the criterion. This is likely due to autocorrelation as evidenced by the high Durbin-Watson statistic of 2.30 and by multicollinearity as revealed by variance inflation factor (VIF) scores of 17.08, 63.27, and 63.36 for the predictors of height, weight, and predicted VO_{2max}, respectively. Tabachnik and Fidell (1996) suggest that VIF values higher than 10 indicate the possibility of muliticollinearity. Additionally, since the height, weight, and age variables are likely to be used by the HRM to predict VO_{2max} (Wier, L.T., Jackson, A.T., Ayers, G.W., & Arenare B., 2006), these measures are partially redundant. Therefore, the model was run again without these problematic predictors (i.e., only predicted VO_{2max} and predicted HR_{max} in the model). The resulting model had an F-score of 12.70 (df1 = 2, df2 = 29, $p < 0.001$) explaining 47% of the variance in the criterion. The beta weight associated with predicted VO_{2max} was significant at $\beta = -.72$ ($p < 0.001$), but the beta for predicted HR_{max} was not. The Durbin-Watson statistic for this reduced model was a more appropriate 2.01 and all VIF values were within the range of acceptability (see Table 5).

Within-participants Tests

When comparing the mean score (199.66 beats min^{-1}) for predicted HR_{max} to the mean (195.91 beats min^{-1}) for the actual HR_{max} using a paired sample (within-participants) t-test, a statistically significant difference was found ($t = 2.80$, $df = 31$, $p < 0.01$). Additionally, the mean score (42.03 ml kg^{-1} min^{-1}) for actual VO_{2max} was significantly different from the mean (44.66 ml kg^{-1} min^{-1}) of predicted VO_{2max} via a paired sample t-test ($t = -2.82$, $df = 31$, $p < 0.01$). Thus, the predicted HR_{max} overestimated actual HR_{max} by 3.75 beats min^{-1}, on average, and the predicted VO_{2max} overestimated actual VO_{2max} by 2.63 ml kg^{-1} min^{-1}, on average (see Table 6).

When using repeated measures ANOVA as a test of the difference in more than three or more means, it is important that the test of the sphericity of the variance-covariance matrix be assessed. In these data, Mauchly's (1940) W score was 0.569 with a Chi-square of 16.91 ($df = 2$, $p < 0.001$). Since this value indicates the matrix is not likely to show sphericity, the Greenhouse-Geisser epsilon value of 0.70 was applied to the degrees of freedom in the F-test. Thus, one-way repeated measures ANOVA revealed significant differences ($F = 51.39$, $p < 0.001$) between mean scores on IC-EE, EE-PHRM, and EE-AHRM during ABDS. Post hoc paired comparisons using the Bonferroni adjustment to $p < 0.05$ to control for Type I error because of multiple comparisons showed significant differences between EE-IC and EE-PHRM as well as between EE-IC kcal.min-1 and EE-AHRM. On average, PHRM overestimated EE by 2.37 kcal min^{-1} and AHRM overestimated EE by 1.96 kcal min^{-1}. However, post-hoc paired comparisons revealed no statistically significant differences between EE-AHRM and EE-PHRM (see Table 7).

Thus, it is clear that differences exist within participants between these three measures of EE (which are designed to reflect the same thing). If PHRM and AHRM are accurate predictors of EE, then EE-PHRM, EE-AHRM, and EE-IC should be strongly correlated between participants. The correlation between EE-PHRM and IC-EE was $r = 0.69$ ($p < 0.001$) and the correlation between EE-AHRM and EE-IC was $r = 0.85$ ($p < 0.001$). Thus, AHRM is a better predictor of EE than is PHRM. For graphs of the observations on these two pairs of variables see Figures 1 and 2.

Discussion

Significant differences in mean gross EE values between IC and both PHRM and AHRM were observed. When compared to IC, the PHRM and the AHRM overestimated EE during the ADBS by 28% (2.4 kcal min^{-1}) and 27% (2.0 kcal min^{-1}), respectively. However, no significant differences between PHRM and AHRM emerged. Therefore, the results of this study indicate that the Polar F6 HRM is not accurate in predicting EE during ADBS performed at a moderate intensity using either predicted or actual measures of VO_{2max} and HR_{max}.

This is the first study to examine the accuracy of a HRM on estimating EE during ADBS in young, college-age females. A previous study examining the accuracy of the Polar S410 on estimating EE during three different modes of exercise (i.e., cycling, rowing, and treadmill exercise) performed at various intensities reported similar findings, among their female participants. . In a sample of 10 female participants, however, PHRM and, to a lesser extent, AHRM, overpredicted EE for all exercise modes and intensities when compared to IC by 33% (2.4 kcal min^{-1}) and 12% (0.7 kcal min^{-1}), respectively. However, in a sample of 10 male participants, no significant differences were observed in mean gross EE measured by IC, PHRM, and AHRM for any exercise mode and intensity Unlike the current study which showed no improvement in accuracy of the Polar F6 for estimating EE when using measured VO_{2max} and HR_{max}, the study by Crouter et al. (2004) showed that the accuracy of the Polar S410 when using measured VO_{2max} and HR_{max} significantly improved estimation of EE.

While an overestimate of 2.4 or 2.0 kcal min^{-1} may not seem too large, when extrapolating the error over an entire exercise session could overestimate one's EE quite substantially. For example, when extrapolating this overestimate to one hour, the PHRM and AHRM would overestimate by 144 and 120 kcal, respectively. In light of this, the use of the Polar F6 may not be an effective tool to be used by individuals monitoring EE during exercise for the purposes of weight management.

Polar's "OwnCal" is based on prediction equations developed and investigated through a series of studies (Hiilloskorpi et al., 1999; Keytel et al., 2005; Polar Electro Oy, 2004b). The factors involved in these equations include body weight, height, age, gender, resting HR, VO_{2max}, and HR_{max} (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003; Keytel et al., 2005; Rennie et al., 2001). Hiilloskorpi et al. (1999), for instance, found that exercise HR, weight, and gender were key factors in predicting EE during treadmill and cycle ergometer exercise at light, moderate, and hard intensities. The equations using gender, body weight and exercise HR as predictors, overestimated EE for cycling and treadmill exercise by an average of 2.03 kcal min^{-1} and 1.56 kcal min^{-1} for, respectively. In a follow up study, Hiilloskorpi et al. (2003) found that in addition to gender and body weight, HR reserve (i.e., the difference between resting and max HR) or HR net (i.e., activity HR minus resting HR) were more accurate than just activity HR alone in estimating EE. The resulting prediction equations yielded a standard error of estimate of 1.08 kcal min^{-1} when HR net was included and 1.01 kcal min^{-1} when HRR was included. Recently, Keytel et al., (2005) developed a regression equation ($r^2 = 0.913$) using HR, weight, gender, age, and VO_{2max} after determining that all factors were integral in predicting EE during treadmill and cycle erogometer exercise at low, moderate, and hard intensities. While these previous studies used different combinations of predictors, they all reported similar degrees of accuracy. The Polar's "OwnCal" in the F6 model uses height, weight, age, gender, HR_{max}, VO_{2max}, resting HR, and exercise HR to estimate EE. Since gender was not a factor in the current study due to only including female participants, regression equations were developed to determine whether the other factors were significant predictors of EE during ABDS. For PHRM, the prediction equation included height, weight, age, gender, predicted HR_{max}, predicted VO_{2max}, predicted resting HR, and exercise HR. For AHRM, the prediction equation included height, weight, age, gender, actual HR_{max}, actual VO_{2max}, actual resting HR, and exercise HR. For both equations, weight was the only significant predictor of EE during ABDS.

An interesting finding in the study is that predicted and actual measures of both VO_{2max} and HR_{max} were significantly different. The PHRM overestimated VO_{2max} by 2.6 ml kg^{-1} min^{-1} and HR_{max} by 3.8 beats min^{-1}. Crouter et al. (2004) reported that the Polar S410 series overestimated VO_{2max} in females by 10.8 ml kg^{-1} min^{-1}. This difference in findings may possibly be due to how the two models calculate VO_{2max} and HR_{max}. The Polar S410 predicts VO_{2max} and HR_{max} based on the user's information (i.e., age, height, weight, gender, physical activity level) and a resting HR. Specifically, the participant's information is entered into the monitor and followed by the participant resting in a supine position for 15 minutes while it records and estimates a VO_{2max} and HR_{max} (Crouter et al., 2004). In contrast, the Polar F6 model used in this study, calculates the VO_{2max} and HR_{max} based on the user's information, but does not include a physical activity level. The Polar F6 HRM also allows the user to enter their own sitting HR instead of recording a resting HR to predict a VO_{2max} and HR_{max} (Polar Electro Oy, 2004a). The sitting HR can be entered in the extra user settings, where their actual VO_{2max} and HR_{max} can be entered as well, thus the HRM is not using a resting HR to predicted VO_{2max} and HR_{max} (Polar Electro Oy, 2004a). While in the current study, the actual and predicted VO_{2max} and HR_{max} were significantly different, EE estimated from PHRM and AHRM not significantly different. Thus, this underscores further that VO_{2max} and HR_{max} does not enhance the prediction of EE using these monitors.

From a practical standpoint, the results from the current study indicate that it is not necessary to enter a measured VO_{2max} and HR_{max} to improve the accuracy of estimating EE using a Polar F6 HRM. Furthermore, users need to be aware of the inaccuracy of the Polar F6 HRM when using this as a tool for weight management/loss purposes. While HRMs remain a practical tool for monitoring HR and intensity during exercise, they are not no accurate in estimating EE. With two studies having found similar results in females, it might be possible for Polar to recalibrate its formula for the "OwnCal" software. A limitation to this study is that it only investigated healthy college aged female students. Thus, the results may not be applicable to males or those who fall outside the age range and fitness levels of the participants involved. This study is also limited by the use of ADBS as its mode of exercise, and may not apply to other forms of exercise.

Another interesting find in this study was the intensity of the exercise. Based on %HRR and $\%HR_{max}$ the intensity was considered to be hard, but $\%VO_2R$ showed the intensity to be moderate (Pollock et al., 1998). This could have been dūe to the theory that the use of arms during ADBS disportionately increases HR compared to VO_2. Since the participants were using their arms during the 20 minute routine, this could have increased their HR.

Thus causing the HRMs to increase EE, this could have led to the HRMs overestimation of EE.

In conclusion, results from this study suggest that regardless of whether the predicted or measured VO_{2max} and HR_{max} is used as predictor variables, the Polar F6 HRM may not accurately estimate the EE of ADBS performed at a cadence of 126 beats min^{-1} on a 6-inch bench. ADBS participants may use the Polar F6 HRM to alter exercise intensity based on HR, but should avoid using it to monitor exercise EE for the purposes of weight control. In addition, it appears that body weight is more of a factor than age, height, VO_{2max} and HR_{max}.

Table 1

Physical Characteristics of Participants (n=32)

	Mean±SD	Range
Height (cm)	164.2 ± 5.2	152.4 ± 175.3
Weight (kg)	61.2 ± 9.2	44.8 ± 85.9
Age (yr)	20.3 ± 1.9	18.0 ± 25.0
Measured Sitting HR (bpm)	70.9 ± 10.9	49.0 ± 98.0
Predicted Sitting HR (bpm)	60.0 ± 0.0	60.0 ± 60.0
Measured VO_{2max} (ml kg^{-1} min^{-1})	42.0 ± 5.7	28.5 ± 54.6
Predicted VO_{2max} (ml kg^{-1} min^{-1})	44.7 ± 2.5	38.0 ± 48.0
Measured HR_{max} (bpm)	195.9 ± 7.3	178.0 ± 217.0
Predicted HR_{max} (bpm)	199.7 ± 1.9	195.0 ± 202.0

Note. Predicted values obtained from a Polar F6 heart rate monitor.

Table 2

Cardiovascular and Metabolic Responses to ADBS (n=32)

	Mean ± SD	Range
Average VO_2 (ml kg^{-1} min^{-1})	24.4 ± 2.2	20.4 ± 29.3
Percent VO_2 Reserve	55.0 ± 9.0	36.0 ± 77.0
Average HR (bpm)	163.3 ± 18.5	115.0 ± 194.0
Percent HR Reserve	74.0 ± 12.0	4.0 ± 95.0
Percent HR Max	83.0 ± 8.0	64.0 ± 97.0
AHRM EE (kcal min^{-1})	9.3 ± 1.7	6.5 ± 14.4
PHRM EE (kcal min^{-1})	9.7 ± 2.3	5.3 ± 16.0
IC EE (kcal min^{-1})	7.4 ± 1.1	5.3 ± 10.2

Note. PHRM and AHRM values obtained from a Polar F6 heart rate monitor.

Table 3

Means, Standard Deviations, and Bivariate Correlations of Variables

	Mean	SD	1	2	3	4	5
1. Height	64.63	2.03	--				
2. Weight	134.60	20.22	.36*	--			
3. Age	20.30	1.86	-.01	.03	--		
4. Predicted Sitting HR	60.00	.00	a	a	a	--	
5. Predicted VO_{2max}	44.66	2.47	.15	-.82***	-.32	a	--
6. Predicted HR_{max}	199.66	1.86	.01	-.03	-1.00	a	32
7. Predicted EE	146.06	35.23	-.04	.63***	-.05	a	- 61***
8. Actual Sitting HR	70.91	10.95	-.14	.12	.07	a	- 22
9. Actual VO_{2max}	42.03	5.69	.25	-.30	.11	a	.38*
10. Actual HR_{max}	195.91	7.28	-.28	.13	.04	a	- 29
11. Actual EE	139.91	25.15	.07	.76***	-.13	a	- 67***
12. IC EE	110.47	16.20	.27	.80***	.00	a	- 65***

Table 3 continued

Means, Standard Deviations, and Bivariate Correlations of Variables

	6	7	8	9	10	11	12
6. Predicted HR_{max}	--						
7. Predicted EE	.05	--					
8. Actual Sitting HR	-.07	.52**	--				
9. Actual VO_{2max}	-.11	-.74***	-.57**	--			
10. Actual HR_{max}	-.04	.51**	.38*	-.32	--		
11. Actual EE	.13	.82***	.16	-.35*	.19	--	
12. IC EE	.00	.69***	.19	-.24	.14	.85***	--

Note. HR = heart rate; EE = energy expenditure; IC = indirect calorimetry

[a]Cannot be computed because Predicted Sitting HR is a constant

*p < .05

** p < .01

*** p < .001

Table 4

Multiple Regression Results for Indirect Calorimetry Using Actual Heart Rate Monitor Data

	Actual Total Energy Expenditure as Criterion					
				95% Confidence Interval for B		
	B	Std. Error	Beta	Lower Bound	Upper Bound	Effect Size[a]
Constant	18.87	99.24		-185.51	223.25	
Height	-.24	1.14	-.03	-2.60	2.11	.00
Weight	.66	.11	.83***	.43	.90	.46
Age	-.37	1.05	-.04	-2.52	1.78	.00
Actual Sitting HR	.22	.22	.15	-.24	.68	.01
Actual VO_{2max}	.28	.46	.10	-.67	1.23	.00
Actual HR_{max}	-.01	.30	.00	-.62	.60	.00
F-score $_{(df1, df2)}$	$7.99_{(6, 25)}$***					
R^2	.66					
Adjusted R^2	.58					

[a]Squared semi-partial correlation

*** $p < .001$

Table 5

Multiple Regression Results for Indirect Calorimetry Using Predicted Heart Rate Monitor Data

	B	Std. Error	Beta	95% Confidence Interval for B: Lower Bound	95% Confidence Interval for B: Upper Bound	Effect Size[a]
Constant	-82.28	239.09		-571.27	406.71	
Predicted VO_{2max}	-4.74	.94	-.72***	-6.66	-2.82	.47
Predicted HR_{max}	2.03	1.25	.23	-.53	4.58	.05
F-score $_{(df1, df2)}$	$12.70_{(2, 29)}$***					
R^2	.47					
Adjusted R^2	.43					

[a]Squared semi-partial correlation

*** p < .001

Table 6

T-tests for Differences in Group Means on HRmax and VO_2max

		Paired Differences (n = 32)			
		mean	sd	t	df
Pair 1	Actual HR_{max}	195.91	7.28		
	Predicted HR_{max}	199.96	1.86	-2.80**	31
Pair 2	Actual VO_{2max}	42.03	5.69		
	Predicted VO_{2max}	44.66	2.47	-2.82**	31

** $p < .01$

Table 7

ANOVA Results for Differences in Group Means on Methods of Calculating Energy Expenditure per Minute

	Mean	sd	Mean differences[a] 1	2
1. Predicted EE kcal·min^{-1}	9.74	.42		
2. Actual EE kcal min^{-1}	9.33	.30	.41	
3. IC-EE kcal min^{-1}	7.34	.19	2.37***	1.96***
F-score[b]	51.39*** (*df* = 1.40)			

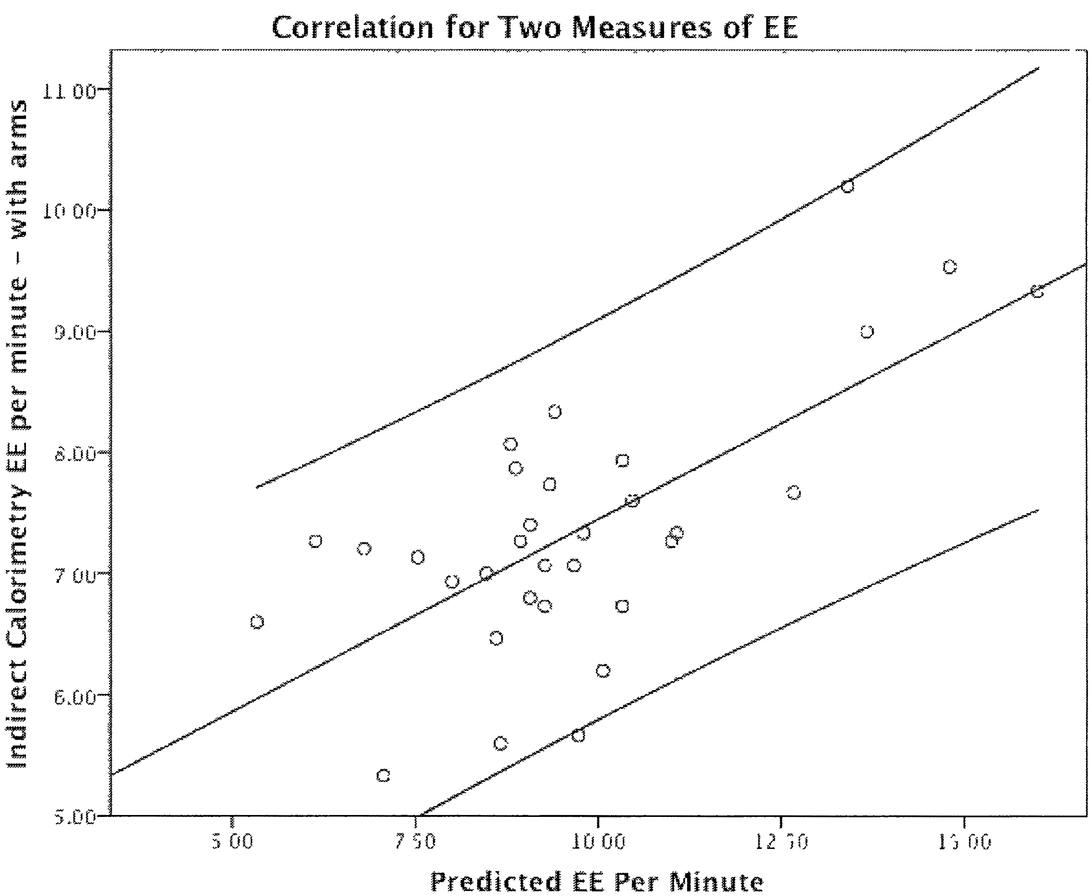
[a]Using Bonferroni adjustments for Type I error

[b]Using Greenhouse-Geisser adjustment to degrees of freedom because of a lack of sphericity in the variance-covariance matrix

*** p < .001

Figure 1.

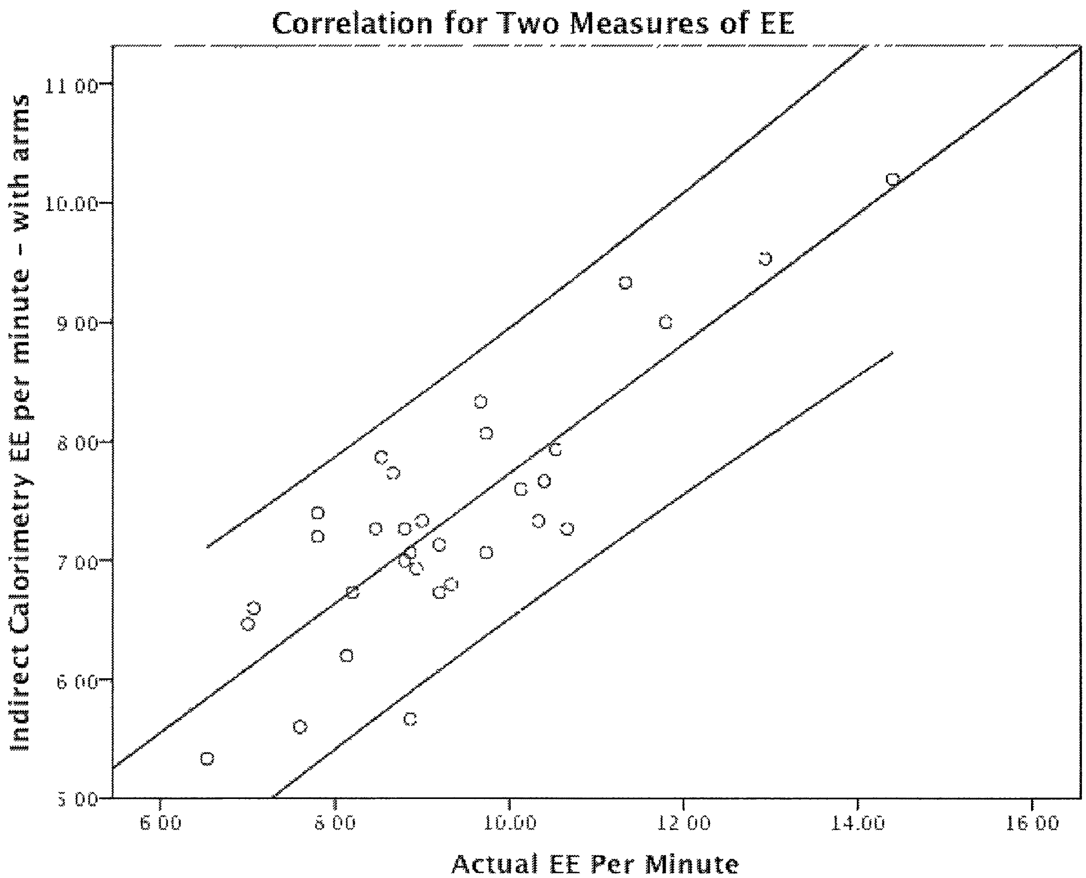
Plot of correlation (r = 0.69, p < 0.001) between predicted EE per minute and IC-EE per minute.



Outer bands indicate 95% confidence intervals.

Figure 2.

Plot of correlation ($r = 0.85$, $p < 0.001$) between actual EE per minute and IC-EE per minute.



Outer bands indicate 95% confidence intervals.

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CHAPTER 2

REVIEW OF ESTIMATING ENGERY EXPENDITURE

Heat rate (HR) has been one of the most common methods for estimating energy expenditure (EE). Many methods to estimate EE from HR have been developed. Individual calibration curves were one of the first attempts to estimate EE from HR. The calibration curves were developed from HR- oxygen consumption (VO_2) regression equation for each individual (Ceesay et al., 1989, Christensen, Frey, Foenstelien, Aadland, & Refusion, 1983; Li, Deurenberg, & Hautvast, 1993; Livingstone et al., 1990; McCrory, Mole, Nommsen-Rivers, & Dewey, 1997; Spurr et al., 1988; Strath, Bassett, Thompson, & Swartz, 2002). The process in estimating EE from calibration curves was very complex and time consuming. This lead research to investigate a more reasonable approach to estimating EE from HR. Estimation equations were developed based on a series of factors such as height, weight, age, percent body fat, maxim oxygen consumption (VO_{2max}) (Hiilloskorpi et al., 1999; Hiilloskorpi, Pasanen, Fogelholm, Laukkanen, & Manttari, 2003; Keytel et al., 2005; Rennie, Hennings, Mitchell, & Wareham, 2001). Estimation equations were more general but still involved time consuming hand calculation for each individual. Estimation EE thus lead to the technology of heart rate monitors (HRM) to be able to estimate EE during exercise (Crouter, Albright, & Bassett, 2004). The research is limited in the accuracy of HRMs estimating EE. Using relevant literature, the purpose of this review is to discern whether: 1) HRMs are accurate in measuring HR, and 2) HR is accurate in estimating EE with the development of calibration curves and estimation equations.

Accuracy of Heart Rate Monitors in Measuring Heart Rate

The methods for measuring HR vary in complexity. The simplest method involves palpating a pulse at either the carotid or radial artery from 6 to 60 seconds (Laukkanen & Virtanen, 1998). While this method is very cost effective, its accuracy is participant to human error. For example, ıf a person is off by one beat when measuring HR for a 6-second period, when extrapolating the 6-second count to a full minute, he/she is actually off by 10 beats. The most accurate and, thus, considered to be the gold standard for measuring HR, is a 12-lead electrocardiogram (ECG) (Laukkanen &Virtanen, 1998). In contrast to the palpation method, however, this is very costly and not practical to use outside of a lab or clinical setting. In light of this many methods for measuring HR have been developed over the previous three decades for the purpose of providing a practical, but yet accurate, method for measuring HR. For instance, in the early 1980's, the first wireless HRM, the Polar PE 2000, was introduced. This chest HRM consisted of a transmitter that was affixed to the chest and measured HR via disposable electrodes or an elastic electrode belt. A HR watch received and displayed the HR data transmitted from the electrodes (Achten & Jeukendrup, 2003; Laukkanen & Virtanen, 1998). Other wireless HRMs, such as the pulse meter and handgrip, were also developed. The pulse meter was affixed to the ear or finger and measured a pulsatile blood flow through the earlobe or finger tip, respectively (Achten & Jeukendrup, 2003; Humen & Boughner, 1984; Macfarlane, Phil, Fogarty, & Hopkins, 1989). While the handgrip HRM, installed in specific exercise equipment, consisted of electrodes that measure HR (Humen & Boughner, 1984). These models have been the most widely investigated, and studies have shown that some are more accurate than others.

In the 1980's, several studies determined that chest HRM's, such as the PE 2000, were among the most accurate HRM for measuring HR when compared to either a 12-lead ECG or a holter monitor (Achten & Jeukendrup, 2003; Humen & Boughner, 1984; Macfarlane et al., 1989). For example, Karvonen, Chwalbinska-Montea, and Saynajakangas (1984) observed an average HR difference of 5 beats per minute (bpm) at most between the Polar PE 2000 and an ECG during various workloads of exercise. Furthermore, Humen and Boughner (1984) reported high correlations (i.e., r =0.94 or greater) between ECG and both chest HRMs (i.e., Respironics Exersentry and Sportronics Pacer 2000) and ear pulse meters (i.e., Tunturi and Amerec) and low to moderate correlations (i.e., r =0.11 to 0.74) between ECG and both finger pulse meters (i.e., Labtron, Teledyne Water Pik, Genesis Exercise Computer,and Novatec) and a handgrip HRM (Entex Bike computer) during stationary cycling at two different intensities of exercise. These findings have been further substantiated by MacFarlane et al. (1989). When compared to HR measurements recorded by an ECG using an ECG simulator and on participants during cycle and treadmill exercise, chest HRMs (i.e., Sports Tester PE 3000, PU -801, Exersentry 3A, and Monark Trim Guide 2000 chest attachment) generally out-performed in terms of accuracy and variability a finger pulse meter (i.e., PU- 701 finger attachment) and an ear lobe pulse meters (PU – 701 ear lobe attachment, Monark Trim Guide 2000 ear lobe attachment, Boso Card II) (Macfarlane et al., 1989). Specifically, when compared to the ECG stimulator, 3 out of the 4 chest HRM (i.e., Extersentry, Monark Chest, and Sports Tester) were the only HRMs to have a mean bias and variability of less than 1.0. The PU-801 became less accurate at HR above 200 bpm.

With research demonstrating that chest HRM are among the most accurate a types of HRM, thus, these devices are a widely accepted method of measuring HR in both clinical and field settings. Their popularity may also be due, in part, to the fact that the HR from more than one participant may be measure simultaneously. For these reasons, many technological advances, including estimating distance traveled, energy expended, programmed target zones, and personalized workouts, have been added to the HRM features. Of these, EE estimates from HR may be the most critical tool for assisting individuals with weight management. However, for this to be a useful tool in facilitating weight management this feature must be accurate. The following section will discuss the accuracy of HRM on estimating EE.

Energy Expenditure Estimated from Heart Rate

Methods for estimating EE based on HR vary in complexity, accuracy, and variability. While some involve the use of elaborate calibration curves (Ceesay et al., 1989; Christensen et al. 1983; Li et al., 1993; Livingstone et al., 1990; McCrory et. al., 1997; Spurr et al. 1988), others involve the use of simple equations (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003; Keytel et al., 2005; Rennie et al., 2001). The most investigated methods for estimating EE based on HR include: 1) calibration curves, which are developed from a HR –VO_2 regression equation (Ceesay et al., 1989; Christensen et al., 1983; Li et al., 1993; Livingstone et al., 1990; McCrory et al., 1997; Spurr et al. 1988) and 2) EE estimation equations based on a number of factors related to EE, such as age, weight, height, gender, heart rate reserve, heart rate net, and VO_{2max} (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003; Keytel et al., 2005; Rennie et al., 2001).

Calibration Curves

In the 1970's, individualized calibration curves were developed to estimate EE for an extended period of time, typically 6 to 24 hours in duration (Ceesay et al., 1989; Christensen et al., 1983; Li et al., 1993; Livingstone et al., 1990; McCrory et al., 1997; Strath et al., 2002; Spurr et al., 1988). This method involves two primary processes: 1) participant calibration, and 2) estimation of EE from HR data. While the methods for participant calibration are complex and vary among research studies (Ceesay et al., 1989; Christensen et al., 1983; Li et al., 1993; Livinstone et al., 1990; McCrory et al., 1997; Spurr et al., 1988,), the regression equations and calibration curves developed in these studies are typically based on HR and VO_2 measurements taken at rest and during various intensities of exercise (Ceesay et al., 1989; Li et al., 1993; Livingstone et al., 1990; McCrory et al., 1997; Spurr et al., 1988,). As reported in the literature, resting measurements were usually recorded while participants relaxed for 5 to 25 minutes in each of the following resting positions: 1) supine lying, 2) sitting, and 3) standing positions (Ceesay et al., 1989; Christensen et al., 1983; Li et al., 1993; McCrory et al., 1997; Spurr et al., 1988). The mean VO_2 for these resting activities were used to determine the Resting Metabolic Rate (RMR) (Livingstone et al., 1990; Spurr et al., 1988). Furthermore, exercise measurements were typically recorded for 3 to 10 minutes per bout. Most studies employed one to four different modes of exercise (i.e., cycling, walking, jogging, and stepping) at one to five different intensities per mode (Ceesay et al., 1989; Li et al., 1993; Livingstone et al., 1990; McCrory et al., 1997; Spurr et al., 1988). Once all of the measurements were collected during participant calibration, flex HR was calculated and individual HR-VO_2 regression equations were developed (Ceesay et al., 1989; Li et al., 1993; Livingstone et al., 1999; Spurr et al., 1988) Briefly, flex HR, used to discriminate between resting and exercise HR, is the mean of the highest resting HR and the lowest exercise HR (Ceesay et al., 1989; Li et al., 1993; Livingstone et al., 1990; Strath et al., 2002; Spurr et al., 1988). HR-VO_2 regression equations were derived from calibrations points obtained during each activity. Each calibration point reflected the mean HR and VO_2 for the sampling exercise period (Ceesay et al., 1989; Li et al., 1993; Livingstone et al., 1990; Strath et al., 2002; Spurr et al., 1988).

Once participant calibration was completed, EE was estimated from HR data collected during field testing. HR was typically measured while participants performed either ordinary (Christensen et al., 1983; Li et al., 1993; Livingstone et al., 1990; McCrory et al., 1997; Strath et al., 2002) or structured activities (Ceesay et al., 1989; Spurr et al., 1988). In most studies, HR monitors were used and recorded HR either every 15 seconds (McCrory et al., 1997) or every minute (Ceesay et al., 1989; Li et al., 1992; Spurr et al., 1988). In those studies, using the calibration curves, minute-by-minute HR was then converted to VO_2. Specifically, for HR that fell below flexHR, the RMR measured during calibration testing was used for resting VO_2 was used. The HR that fell at or above flex HR was converted to VO_2 based on the individualized HR-VO_2 regression equations. The estimated EE was then calculated from VO_2 by using the Weir formula (Christensen et al., 1983; McCrory et al., 1997) or a slightly modified version (Ceesay et al., 1989). Finally, total estimated EE was then determined by summing together all of the minute-by-minute EE estimations (Livingstone et al., 1990).

Previous research indicates that calibration curves are fairly accurate in determining EE over an extended period of time (Ceesay et al., 1989; Livingstone et al., 1990; Spurr et al., 1988). For instance, high correlations (i.e., $r = 0.87$ to 0.94) have been reported between total EE estimated from calibration curves and indirect calorimetry (Ceesay et al., 1989; Spurr et al., 1988). Using a slightly different standard, Livingstone et al. (1990) found that the calibration curves and doubly labeled water methods produced similar estimates of total EE. On average, calibration curves overestimated total EE by $2.0 \pm$

17.9% (Livingstone et al., 1990). While research on the accuracy of calibration curves in the estimating of total EE is fairly consistent, research on its accuracy in estimating EE of specific activities is both limited and discordant. For example, using calorimetry as the standard, Spurr et al. (1988) showed a high degree of accuracy in estimating EE from calibration curves during exercise (i.e., $r = 0.94$, $SEE = 0.081 kcal\ min^{-1}$). This high correlation may have been due to the fact that same the exercise was used during both the calibration phase and the field testing. In contrast, Strath et al. (2002) reported that calibration curves significantly overestimated measured minute-by-minute EE and underestimated the time spent in resting/light activity by 45 ± 51 minutes, overestimated time spent in moderate activity by 38 ± 43 minutes, and marginally over estimated time spent in hard activity by 6 ± 9 minutes, over a 6 hour period. Ceesay et al. (1989) showed that the EE estimated from calibration curves for various bouts of exercise was on average 11.6 % lower than EE estimated from whole body calorimetry. This may have been due, in part, to the fact that some exercises did not raise the HR above the flex HR. Either the activities chosen may have not been intense enough or flex HR was set too high during the calibration period (Ceesay et al., 1989). Research has indicated that the relationship between HR and VO_2 is not as linear at rest and during light intensity exercise compared to higher intensities. At lighter intensities there is a disproportionate increase in VO_2 compared to HR. Perhaps, the accuracy is lost, lending an explanation, that the use of calibration curves may underestimate EE at this intensity of exercise. Thus, explaining the observation reported by Ceesay.

A potential problem with using flex HR is that HR during light intensity exercise is typically below flex. Thus, for any HR below flex, EE is based on RMR. As reported above, during light exercise, EE is underestimated when using calibration curves. In light of these potential problems, Li et al. (1993) did not use flex HR to discriminate between rest and exercise. Instead, the researchers developed a logistic regression curve to estimate EE. These curves reflected variation in HR that are commonly not accompanied by proportional changes in EE during light exercise (Li et al., 1993). Furthermore, Li et al. (1993) also suggested that individual calibration curves should be developed immediately before the HR recording period. When the curve from one occasion was applied to another, the EE ranged from a dramatic overestimation of 2738 kJ/16h to underestimation of 2986 kJ/ 16h. In other words, when a participant's own calibration curve was used on different days other than the day it was originally designed for, there is still a possibility of inaccuracy. Also, noteworthy is that calibration curve should be individual and not an average group curve. When a group calibration curve was used instead of individual curves, a mean difference of 2 SD was found between the two curves (Li et al., 1993). Finally, the researchers suggested that the calibration curves be based on as many activities as possible to reflect real life scenarios. In this study, Li et al. (1993) employed 18 and 9 different activities (including a variety resting, activities of daily living, and exercise) to create the calibration curves and found 9 activities to be unacceptable when compared to 18.

Other modifications to estimate EE using calibration curves have been developed. McCrory et al. (1997) used two individual regression lines, one for activity HR ranges and one for sedentary HR ranges. This method still uses flex HR to discriminate between which of the two curves to use. The primary difference in this method and others that employed the flex HR method is that RMR is not used to estimate EE for HRs that fall below flex. Even though that these methods rely heavily on the accuracy of the flex HR the research finds that is still worth using. This is due primarily because these studies are looking at an extended period of time and not just an exercise session. McCrory et al. (1997) also investigated the between day and within day variation of creating calibration curves and concluded that resting measurements in the supine and sitting positions were higher in the afternoon when compared to the morning. McCrory et al. (1997) also confirmed that there is no significant difference between days in HR and VO_2. McCrory et al. (1997) and Livingstone et al. (1990) agree that the use of HRM is an appropriate measure for groups but not for individuals.

The previous studies confirm the fact that to develop these curves are very complex and depending on the particular method employed, vary in degree of accuracy. The time of day, number of activities, the need to be developed for individuals, and to be recreated each time they are used are all factors why this process is very complicated and time consuming. Livingstone et al. (1990) states that flex HR is one of the major potential errors with this calibration method, when applying it in the field setting. Thus, the research is not convincing that the calibration curves are appropriate for estimating EE for a single exercise session.

Development of Energy Estimation Equation

In the 1990's, estimation equations using HR and a combination of other factors related EE, such as age, height, weight, gender, heart rate reserve, heart rate net, and VO_{2max}, were developed as an easier less complicated approach to the calibration curves for estimating exercise EE (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003; Keytel et al., 2005; Rennie et al., 2001). Compared to the two complicated processes involved in the calibration curve method (i.e., development of individualized calibration curves and field testing), the development of estimation equations involves only baseline testing. The baseline tests usually consisted of measurements, such as height, weight, percent body fat, VO_{2max} or sub maximal test, and in some cases resting HR and VO_2 were taken as well (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003; Keytel et al., 2005; Rennie et al., 2001). For example, Hiilloskorpi et al. (1999) baseline tests included height, weight, and sub maximal cycle ergometer and maximal treadmill test. During the sub maximal and maximal test, HR and VO_2 were recorded every minute, and VO_2 was converted to EE by the Weir formula, during the last minute of each of 3 minute incremental stage. This determined EE was considered the measured EE, and was compared with estimation equation that was developed by the baseline measurements. Keytel et al. (2005) baseline measurements included height, weight, percent body fat (sum of 7 skin folds), and VO_{2max}. Keytel et al. (2005) used the VO_{2max} test to determine maximum running speed or peak power output, which was then used on the second visit for the same participants to perform sub maximal test. Participants chose which mode of exercise to perform the sub maximal test consisted of three workloads (i.e., on the cycle each work load was 15 minutes, on the treadmill each workload was 10 minutes). Minute-by-minute HR was recorded using the Polar Vantage HRM. During the last 5 minutes of each workload EE was estimated from VO_2 using the Weir formula. The last 5 minutes was also used to calculate the predicted EE based on the estimation equations. Once the data was collected from the baseline tests then all data points were used to generate the estimation equation (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003; Keytel et al., 2005; Rennie et al., 2001). The data was normally entered into a generalized linear regression model with random effects (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003). Typically, a backward selection method, such as the Wald test, was used to remove non significant predictive variables (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003). This process was used to eliminate any of the baseline measurements that did not improve the accuracy of estimating EE through the estimation equations when compared to the actual measured EE.

Hiilloskorpi et al. (1999) measured HR, weight, age, and gender and reported that the estimation equation factors that had significant interactions with EE were only HR, weight and gender. Gender was used because men usually have more fat –free mass than women and have a higher EE during the same exercise (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003). Hiilloskorpi et al. (1999) reported that the total error when compared to indirect calorimetry was 2.03 kcal min^{-1} during cycling and 1.56 kcal min^{-1} during walking with a mean overestimation of 17.9 % for cycling and 6.6% for walking. In a follow up Hiilloskorpi et al. (2003) created separate estimation equations for males and females, thus eliminating gender as a predictive factor. Also, three different models were created with weight being the only factor that was the same for all three models (Hiilloskorpi et al., 2003). The models either used HR reserve (i.e., the difference between resting and max HR), HR net (i.e., the activity HR minus resting HR), or activity HR (Hiilloskorpi et al., 2003). Hiilloskorpi et al. (2003) reported that the most accurate equations included HR reserve (SEE = 1.01 kcal min^{-1}) or HR net (SEE = 1.08 kcal min^{-1}), while the least accurate equation included activity HR (SEE = 1.41 kcal min^{-1}). In a more recent study, not only found that HR, weight, and gender were contributing factors, but also age and VO_{2max} (Keytel et al., 2005). In this study participants represent a wider range of ages (19-50 years) thus the mean age for males was 31 years and for females was 30 years compared to the study by Hiilloskorpi the mean age for males was 40 years and females was 38 years (Hiilloskorpi et al., 1999; Keytel et al., 2005). Perhaps this difference may explain the difference in the findings between there two studies. Furthermore, Keytel et al. (2005) found that adding the factor of VO_{2max} in to the estimation equation improved the correlation between estimated EE and EE measured via indirect calorimetry from 0.857 to 0.913. Logically, VO_{2max} can be considered a key factor in estimating EE during exercise since EE during exercise may be affected by one's level of fitness (Keytel et al., 2005).

In a different approach in developing estimation equations, Rennie et al. (2001) investigated the use of calibration curves to estimate EE without having to develop individual calibration. Different estimation equations were used to estimate resting EE, flex HR, and the slope and intercept of the regression line between EE and HR during exercise. The estimation equation for resting EE included gender, weight, and sitting HR as the factors that and significant interactions. A moderate correlation ($r = 0.73$, $P < 0.001$) between the observed mean resting EE (via indirect calorimetry) and the estimated mean resting EE from the model was observed on a independent sample. For the flex HR estimation equation, the factors that were significant included BMI, gender, and sitting HR. A high correlation ($r = 0.93$, $P < 0.001$) between the observed mean flex HR and the estimated mean flex HR was observed on an independent sample. Lastly, the slope and intercept estimation equations significant factors included age, weight and gender. When compared to an independent sample, a moderate correlation was reported for slope ($r = 0.76$, $P < 0.01$), and a lower correlation was reported for intercept ($r = 0.59$, $P < 0.01$) between the observed mean slope and intercept and the estimated mean slop and intercept. This method is an alternative method to calibration curves but there is not a high correlation with all different equations for this specific method. In theory, this is a good ıdea to put together a series of estimation equations to predict calibration curves, but the accuracy and the time is still a major concern for research purposes.

Estimation equations are less complex and are an easier approach compared to calibration curves. Estimation equations are more efficient in estimating EE for specific exercise.

The previous research has not been clear in what specific contributing factors should be involved in the estimation equations. HR, weight, and gender are the only factors that were used throughout these equations that have been developed. Keytel et al. (2005) is the one of the most recent studies and its findings show that VO_{2max} to be a significant contributing factor, but a limitation is this is not manageable for large studies and for the general population. The estimation equations still have to be calculated for each individual which again can be time consuming. Estimation equations are more general but take into account an average HR to be placed into the equation. With the technology allowing minute-by-minute recordings of HR these equations are not effectively using what is available. HR fluctuates minute to minute and average HR may not give an appropriate record of what was actually happening during the total exercise session. HRMs are now starting to combine minute-by-minute HR recording and estimation equations to estimate EE.

Estimating Energy Expenditure using Heart Rate Monitors

HRMs have had the technology of minute-by-minute HR recording since the 1980's, but not until the late 1990's the HRMs started to develop newer technology. Polar Electro, Inc., is one of the leading manufactures of HRMs, and developed what is known as the "OwnIndex" (Crouter et al., 2004; Laukkanen & Virtanen, 1998). This feature allows for personal user information to be entered into the HRM and be used to estimate VO_{2max} and HRm_{ax} The HRMs can also estimate EE by using the feature of "OwnCal". Estimation equations are the foundation of this new technology, and allow for HRMs to do the calculations on its own. As a research perspective, this alleviates the struggle of hand calculation for every participant; this will save more time and can allow for more participants to be used. These features have been around for over a decade, but the research is limited to just one main study.

In 2004, Crouter et al. (2004) was the first study to investigate the accuracy of the Polar S410 in estimating EE during exercise (treadmill, cycle ergometer, and rowing ergometer). The purpose of this previous study was to examine if a predicted HR_{max} and VO_{2max} produced by the HRM or if entering an actual measured HR_{max} and VO_{2max} into the HRM improved the accuracy of estimating EE (Crouter et al., 2004). To get the predicted HR_{max} and VO_{2max} the HRM uses an estimation equation using the user's information (age, height, weight, gender and physical activity level) and a resting HR. The physical activity was either categorized as low, moderate, or high. The resting HR was taken while the participant rested for 15 minutes while the HRM predicted HR_{max} and VO_{2max}. The actual measurements of HR_{max} and VO_{2max} were conducted by using a graded treadmill maximal test. A series of sub maximal exercises were performed while participants wore two HRM watches one with the predicted measurements and the other with the actual measurements. The participants performed three sub maximal exercises at three different workloads with 10 minutes at each level. The workloads were self selected using the Borg scale of rate of perceived exertion (RPE). The three workloads were at an RPE of 3, 5, and 7 which were considered moderate, hard, and very hard respectively. The first 5 minutes at each workload allowed the participants to reach a steady state and during the last 5 minutes, HR and RPE were recorded from the two monitors and actual EE was measured from indirect calorimetry for every minute. To eliminate any bias with self selecting workloads participants were blind to their actual workload (i.e., speed, pedal rate, and power).

There were no differences in mean EE for the predicted measurement HRM, actual measurement HRM, and indirect calorimetry in all exercises for males (Crouter et al., 2004). On the other hand for females, the predicted measurement HRM significantly overestimated the mean EE on the treadmill by 2.4 kcal min^{-1}, the cycle ergometer by 2.9 kcal min^{-1}, and the rower ergometer by 1.9 kcal min^{-1} (Crouter et al., 2004). The actual measurement HRM still overestimated mean EE but it did significantly improve the estimation, with mean error improving from -2.4 kcal $min^{-1}$to -0.7 kcal min^{-1}. (Crouter et al., 2004). One of the reasons for the improvement for the females with the actual measurement HRM, is that the predicted measurement HRM overestimated VO_{2max} by 10.8 ml kg min^{-1} which would lead to a greater overestimate of EE (Crouter et al., 2004). A limitation to this research was the participants performed three stages on each piece of equipment, with these stages being based on the participants RPE. This relies on the participants' opinion on how hard they feel they are working. Thus, allowing for the workloads not to be standard through out all of the participants.

Summary and Conclusions

Heart rate monitors are a valuable tool in measuring HR. Research has shown that chest HRMs are accurate in measuring HR when compared to an ECG (Achten & Jeukendrup, 2003; Humen &Boughner, 1984; Macfarlane et al., 1989). EE has been estimated by HR with the use of individualized calibration curves. Calibration curves are considered to be accurate when estimating total EE over an extended period of time (Ceesay et al., 1988; Livingstone et al., 1990; Spurr et al., 1988). However, the research is discordant with regards to the accuracy of calibration curves in estimating EE for specific exercise (Ceesay et al., 1988; Spurr et al., 1988; Strath et al., 2002). While the accuracy of calibration curves is unclear, its practicality is questionable. Thus, research has turned its attention to more pragmatic approaches e.g., the use of estimation equations to estimate EE. These equations use easily attainable factors e. g. HR, weight, and gender (Hiilloskorpi et al., 1999; Hiilloskorpi et al., 2003; Keytel et al., 2005; Rennie et al., 2001). Furthermore, the newer technology of HRMs has the built in the capability to estimate EE using these equations. With only one study investigating the accuracy of one brand of HRM (i.e., Polar HRM), in estimating EE, further research on the accuracy of other HRMs. While this previous study chose to examine the S410 HRM (Crouter et al., 2004), there are several brands of HRMs by Polar that have the technology to estimate EE. Further, this previous study also only investigated three modes of exercise, such as, treadmill, cycle, and arm ergometer. There are other modes of exercise, such as aerobic dance bench stepping (ADBS), that individuals might benefit from wearing a HRM while participating.

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APPENDIX A

CONSENT FORM

Consent Form for Participation in the Accuracy of the Polar "OwanCal" in Estimating Energy Expenditure during Aerobic Dance Bench Stepping

IRB# 2008A5523

Department of Health, Physical Education, and Recreation, Texas State University

INTRODUCTION AND PURPOSE OF COMPREHENSIVE TESTING

You have been asked to participate in a research study to determine the accuracy of the Polar "OwnCal" heart rate monitors (HRM) in estimating energy expenditure during aerobic dance bench stepping (ADBS). The purposes of this study are to discern whether: 1) the to examine the accuracy of the Polar F6 for estimating EE in a sample of women during ADBS using one's predicted VO_{2max} and HR_{max} and 2) to determine whether the use of measured VO_{2max} and HR_{max} improves the accuracy of the Polar F6 for estimating EE. This study will take place in the Human Performance Laboratory at Texas State University-San Marcos. Briefly, you will be required to wear the Polar F6 heart rate monitor while following a 20-minute ADBS video. You were recruited because you are female and familiar with ADBS and are likely to be able to follow an ADBS video. Your participation is voluntary. Before you decide to participate, read this form and ask questions about anything that you do not understand. My name is Annie Lowe, I am the primary researcher, and I am completing this study as part of my requirements for graduation with a Master's degree in Exercise Science. I can be reached by phone at 512-245-1970 or by email at AL1122@txstate.edu.

PROCEDURES

If you agree to participate in this research study and are apparently healthy (as determined by a comprehensive health appraisal), you will be expected to do the following:

You will meet with a staff member at Texas State University for an initial consultation and baseline testing. During this 45-minute visit, you will be expected to:

Fill out a form about your health history.

This study is intended for apparently healthy female adults exhibiting no signs or symptoms suggestive of heart, metabolic (diabetes), and pulmonary disease. You cannot participate in the study if you: (a)have been diagnosed with heart, lung (including severe asthma), liver, metabolic (diabetes) or kidney disease, , (b) have recently experienced a musculoskeletal injury, (c) have been told by a health care provider to not exercise, (d) are pregnant (or think that you might be pregnant), or have experience one or more of the following: (1) Pain or discomfort in the chest, neck, jaw, arms, or other areas, (2) Unusual shortness of breath at rest or with mild activity, (3) Dizziness or fainting, (4) Difficulty breathing while lying down or sleeping, (5) Ankle swelling, (6) Rapid or pounding heart beats, and (7) Periodic numbness/pain in the arms or legs

Be measured for body weight and height in exercise clothes, but without shoes.

Be measured for aerobic fitness on a treadmill. Aerobic fitness will be determined by measuring your maximum O_2 uptake during the treadmill test. This test will follow the Bruce Protocol. You will begin the maximal test by walking at 1.7 miles per hour (mph) up a 10% grade. Every 3 minutes, the treadmill speed will increase to 2.5 mph, 3.4 mph, 4.2 mph, 5.0 mph, 5.5 mph, and 6.0mph, respectively. Also, every 3 minutes, the treadmill grade will increase by 2%. The intensity of the exercise will continue to be increased until you experience volitional exhaustion (in other words, you can't maintain the pace). The test typically takes 10 to 12 minutes.

Following the initial visit, you will be asked to return to the lab two more times (each visit will be separated by at least 2 days of recovery). During visits 2 and 3, you will follow a 20-minute ADBS video. During the 2 visits you will either be asked to use your arms or to keep yours arms on your hips during the routine. The routine will be done on a 6 inch bench, at a cadence of 126 beats per minute. This is a typical height and cadence of an ADBS class. While following the video, you will be wearing a HRM strap that will be affixed to the chest. Sponges will be placed between the strap and your skin to ensure that heart rate (HR) will be read through the entire routine. Two HRM watches will be worn. Each watch will be programmed with different settings to predict your energy expenditure (EE). A mouthpiece will also be worn that will be hooked up to a metabolic cart which will analyze your O2 consumption.

POTENTIAL RISKS OR DISCOMFORTS

This study may involve a few risks to your health:

There exists the possibility of certain changes occurring during ADBS and graded maximal exercise test. These include abnormal blood pressure, fainting, irregular or fast heart rhythm, and in rare instances, heart attack, stroke, or death. Although there has been no research identifying a college-age student's risk of death during graded maximal exercise, the studies on the risk of death during graded maximal exercise for middle-aged men is 1 death per 10,000 tests. Every effort will be made to minimize these risks by evaluation and preliminary information related to your health and fitness and by careful observations during testing. You will only be allowed to participate if you are at low risk for cardiovascular disease. In addition, emergency equipment is located in the building.

Furthermore, to ensure your safety, you must tell us about your current health and health history as well as if you **experience light headedness, unusual breathlessness, nausea,**

A very fast heart rate, very slow heart rate, a pounding sensation in their chest, chest pain, pain in the arms, dizziness, or difficulty breathing. If you do experience these unusual signs and symptoms during exercise, stop exercising and notify the test administrator immediately. The test administrator will contact 911 if needed. It is important to note that the intensity and duration of the exercises, other than the maximal testing, that will be used in this study are no greater than that employed during typical group exercise (e.g., aerobic dance bench stepping) classes. During exercise, it is normal for heart rate and breathing rate to increase and for sweating to occur.

You may also experience slight soreness that will lessen within a few days.

There are no psychological, social or legal risks associated with these evaluations.

The HRM monitors are common tools used to gauge exercise intensity and pose no risk to your health.

Should you experience a major complication as a result of exercise testing, we will call 911, send you to the University Health Center, or refer you to your physician (depending on the severity).

POSSIBLE BENEFITS

The results from this investigation may be of some benefit to you. Specifically,

This study will test your cardiovascular endurance. You will be provided with information about your current level of fitness.

This is a test that is an effective measure of cardiovascular endurance that usually costs $100 or more dollars in a clinical setting.

This study will provide insight to whether the Polar F6 is accurate in estimating energy expenditure during ADBS, and whether the use of arms will decrease this accuracy. Upon completion of the study, I will provide you with a summary of the findings. If this study shows that the heart rate monitors are accurate, then you may want to start using similar equipment to regulate your intensity and monitor your energy expenditure during exercise.

As a participant you can request to see the results of the study.

COMPENSATION

For participating in this study, you may receive extra credit depending on the class in which you were recruited. For those enrolled in the intermediate aerobics class, you will receive an extra 10 points added to your total participation points out of 100 possible. If you do not want to participate in the study, but would like to receive the extra credit, then you will be given a research article and asked to write a two to three page paper on the accuracy of estimating energy expenditure with heart rate monitors.

CONFIDENTIALITY

Your records will be kept private as much as the law requires. If you give us permission, your information may be shared with your health care provider. Personal information will be stored in a locked file cabinet in Dr Lisa Lloyd's office for five years, after which, it will be destroyed. We will obtain additional written consent from you if this data will be used for other research purposes.

When the results of the research are shared, no information will be included that would negate participant confidentiality.

TERMINATION OF TESTING

You are free to decide if you would like to take part in testing. If you choose not to take part, it will not affect your grade in any course that you're currently enrolled in. Also, should you choose to participate, you may withdraw from the study at any time without prejudice or jeopardy to your standing in the University. If you decide to stop participating in the study, please notify myself or Dr. Lisa Lloyd immediately. In addition, I may end your participation in testing without your consent if I believe that you may be in danger (i.e., based on physical symptoms experienced during the evaluations such as increased heart rate, breathing difficulty, etc.).

AVAILABLE SOURCES OF INFORMATION

For questions you may have about your rights as a participant in this evaluation, please consult with:

Principle Investigator: Annie Lowe

Phone Number: 512-245-1970

Pertinent questions about the research and research participants' rights, and research-related injuries to participants, should be directed to the IRB chairperson, Dr. John Lasser (512-245-3413), and to the OSP Administrator, Ms. Becky Northcut (512-245-8491).

AUTHORIZATION

"I have read and understand this consent form. Questions concerning these procedures have been answered to my satisfaction by Ms. Annie Lowe, the Principle Investigator. I agree to participate in testing. I understand that I will receive a copy of this form. I voluntarily choose to participate, but I understand that my consent does not take away any legal rights in the case of negligence or other legal fault of anyone who is involved in this study. I further understand that nothing in this consent form is intended to replace any applicable Federal, state, or local laws. I also understand that I may withdraw from this study at any time without penalty."

Participant's Name (Printed): ______________________________

____

Participant's Signature: ______________________________

Date: ______________

Principle Investigator's Signature: ______________________________

Date: ______________

APPENDIX B

PRE –TEST INSTRUCTIONS

The Accuracy of the Polar "OwnCal" in Estimating Energy Expenditure during Aerobic Dance Bench Stepping

Purpose: To determine the accuracy of the Polar "OwnCal" in estimating energy expenditure.

Participant Requirements:

- Participants must have 2 months of aerobic dance bench stepping experience
- Participants must be considered low risk – based on health appraisal form
- Participants must be able to commit to 3 visits to the human performance lab (Jow A208)
    - 1st visit – filling out health appraisal form, and be measured for height, weight, and aerobic fitness (approx 45 min)
    - 2nd & 3rd visit – will follow a 20-minute step video while wearing HRMs and headgear (which is hooked up to a metabolic cart to analyze your O2) – approx 30 min

Before coming to all 3 visits please follow the following criteria:

- Refrain from ingesting food, alcohol, or caffeine or using tobacco products within 3 hours of testing
- Get the recommended 6-8 hours of sleep on the night prior to each testing day
- Refrain from strenuous exercise 24 hours prior to testing
- Wear comfortable clothes and exercise appropriate shoes on testing day
- Drink plenty of fluids in the 24 hours prior

*If interested please contact Annie Lowe at al1122@txstate.edu to set up your first visit to the lab.

APPENDIX C

HEALTH APPRASIAL

Health Appraisal

Yes	No	
Do you have a physician in town? **Name:**		
Yes	**No**	**History of Heart Disease – Have you experienced:**
❍	❍	A heart attack? If so, when?
❍	❍	Heart surgery? If so, when?
❍	❍	Cardiac catherization? If so, when?
❍	❍	Coronary angioplasty (PTCA)? If so, when?
❍	❍	Pacemaker/implantable cardiac defibrillator/rhythm disturbance? If so, when?
❍	❍	Heart valve disease? If so, when was it diagnosed?
❍	❍	Heart failure? If so, when?
❍	❍	Heart transplantation? If so, when?
❍	❍	Congenital heart disease? If so, when was it diagnosed?
Yes	**No**	**Current Health Status - Do you have:**
❍	❍	Diabetes? If so, when was it diagnosed?
❍	❍	Asthma or other lung disease? If so, when was it diagnosed?
❍	❍	Kidney disease? If so, when was it diagnosed?
❍	❍	Liver disease? If so, when was it diagnosed?
❍	❍	A known heart murmur (associated with cardiomyopathy or aortic stenosis)?
❍	❍	If you are a female, are you pregnant or do you think that you might be pregnant?
Yes	**No**	**Symptoms – Do you experience:**
❍	❍	Chest discomfort with exertion?

❍	❍	Chest unreasonable breathlessness or unusual fatigue at rest, with mild exertion, or during usual activities?
❍	❍	Dizziness, fainting, or blackouts?
❍	❍	Difficulty breathing when lying flat or when asleep?
❍	❍	Ankle swelling?
❍	❍	Forceful or rapid heartbeats?
❍	❍	Numbness in legs or arms from time to time (or burning or cramping sensation in your lower legs when walking short distances)?
❍	❍	Unusual fatigue or shortness of breath with usual activities.

If you answered yes to any of the questions above, you will need to receive physician approval before you can participate in fitness testing or an exercise program. Do you have a physician that we send a copy of the medical referral form to or would you like for me to set up an appointment at the Student Health Center?

(Office Use Only) Action taken if client answered yes:

Medical Referral form completed, and client was instructed to make an appointment with his/her physician or seek medical services at the Student Health Center (245-2161).

No action. Client declined to participate.

Yes	**No**	**Cardiovascular risk factors:**
❍	❍	Do you smoke or have you quit smoking within the last6 months?
❍	❍	Have you been diagnosed with high blood pressure (i.e., is your blood pressure 140/90 mmHg or greater); do you take blood pressure medication; or do you not know your blood pressure? (In other words, check 'yes' if you do not know your blood pressure level.)
❍	❍	Have you been diagnosed with high cholesterol (i.e., is you blood cholesterol greater than 200 mg/dL); do you take cholesterol-lowering medication; or do you not know your cholesterol level? (In other words, check yes if you do not know your cholesterol level)

❍	❍	Has a close blood relative experienced a heart attack or heart surgery, or sudden death from a heart attack or stroke before age 55 (father or brother) or age 65 (mother or sister)?
❍	❍	Have you been diagnosed with high blood sugar, or do you take medicine to control your blood sugar?
❍	❍	Are you physically inactive (i.e., do you get less than 30 minutes of physical activity on at least 5 days per the week)?
❍	❍	If you are a male, are you 45 years or older? If you are a female, are you 55 years or older?
(Office Use Only)		**Height:** _____ **Weight:** _____ **BMI:** ______ **Waist circumference:** _____ **%BF:** _____
		Other health issues that may warrant physician approval before engaging in physical activity.
❍	❍	Have you ever been told not to exercise by a health care provider?
❍	❍	Do you have problems with your muscles, bones, or joints?
❍	❍	Do you have concerns about the safety of exercise?
❍	❍	Are you taking prescription medications? If so, please list:

Medication	**Dosage**

I certify that the information included on this form is correct.

____________ ________________________________

Date Signature of Client

____________ ________________________________

Date Signature of Test Administrator

(Office Use Only) Risk Status: ❍ 1. Low ❍ 2. Moderate ❍ 3. High

❍ Diabetes ❍ Heart Disease ❍ Lung Disease ❍ Kidney Disease ❍ Liver Disease ❍ Pregnant

APPENDIX D

DATA COLLECTION FORMS

Participant Name: ____________________ Visit # __________

ARMS NO ARMS

	AHRM	**PHRM**
Total kcals:		
Average HR:		
Max HR:		

Minute	VO2	VCO2	RER	A- HR	A - kcal	P-HR	P-Kcal
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
Average:							
			Total:				

APPENDIX E

DATA

Participant	PHRM Rate of EE	PHRM EE	AHRM Rate of EE	AHRM EE	IC Rate of EE	IC EE
1	9.07	136.00	9.33	140	6.80	102
2	11.00	165.00	10.67	160	7.27	109
3	7.53	113.00	9.20	138	7.13	107
4	9.27	139.00	9.73	146	7.07	106
5	13.40	201.00	14.40	216	10.20	153
6	5.33	80.00	7.07	106	6.60	99
7	9.27	139.00	8.20	123	6.73	101
8	8.47	127.00	8.80	132	7.00	105
9	16.00	240.00	11.33	170	9.33	140
10	6.13	92.00	8.47	127	7.27	109
11	8.87	133.00	8.53	128	7.87	118
12	10.07	151.00	8.13	122	6.20	93
13	10.33	155.00	9.20	138	6.73	101
14	9 33	140.00	8.67	130	7.73	116
15	9.67	145.00	8.87	133	7.07	106
16	8.00	120.00	8.93	134	6.93	104
17	7.07	106.00	6.53	98	5.33	80
18	9.07	136.00	7.80	117	7.40	111
19	9.40	141.00	9.67	145	8.33	125
20	10.47	157.00	10.13	152	7.60	114
21	8.67	130.00	7.60	114	5.60	84
22	14.80	222.00	12.93	194	9.53	143
23	9.80	147.00	9.00	135	7.33	110
24	10.33	155.00	10.53	158	7.93	119
25	12.67	190.00	10.40	156	7.67	115
26	8.60	129.00	7.00	105	6.47	97
27	11.07	166.00	10.33	155	7.33	110
28	8.93	134.00	8.80	132	7.27	109
29	9.73	146.00	8.87	133	5.67	85
30	6.80	102.00	7.80	117	7.20	108
31	8.80	132.00	9.73	146	8.07	121
32	13.67	205.00	11.80	177	9.00	135
mean	9.74	146.06	9.33	139.91	7.36	110.47
st dev	2.35	35.23	1.68	25.15	1.08	16.20
min	5.33	80.00	6.53	98.00	5.33	80.00
max	16.00	240.00	14.40	216.00	10.20	153.00

Participant	AbsoluteVO2	Rel VO2	%VO2R	Avg HR	%HRR	%HRMAX
1	1.373	23.24	53%	164	76%	85%
2	1.448	27.70	56%	189	88%	93%
3	1.467	25.41	49%	142	71%	79%
4	1.424	26.55	55%	165	81%	86%
5	2.097	24.41	63%	178	89%	93%
6	1.327	22.12	40%	115	48%	65%
7	1.345	24.87	62%	168	80%	87%
8	1.413	27.51	56%	163	77%	84%
9	1.879	22.71	77%	194	91%	95%
10	1.476	21.94	36%	121	48%	64%
11	1.583	29.27	62%	161	71%	83%
12	1.265	24.63	63%	181	83%	90%
13	1.373	24.76	59%	181	83%	89%
14	1.562	25.18	55%	161	66%	78%
15	1.437	22.26	49%	156	70%	78%
16	1.403	24.40	48%	151	67%	78%
17	1.072	23.94	54%	159.5	72%	82%
18	1.484	24.73	62%	159.5	67%	80%
19	1.671	28.50	65%	165	79%	86%
20	1.529	24.38	55%	169	78%	86%
21	1.15	20.74	45%	158	66%	79%
22	1.89	26.48	68%	190	95%	97%
23	1.486	25.95	64%	169	80%	88%
24	1.6	21.08	47%	155	70%	79%
25	1.56	23.03	54%	185	79%	85%
26	1.301	24.89	65%	162	73%	84%
27	1.481	20.95	56%	169	80%	89%
28	1.469	25.05	55%	158	69%	82%
29	1.151	20.42	47%	171	80%	88%
30	1.468	24.47	41%	133	47%	67%
31	1.631	24.24	45%	145	61%	73%
32	1.809	26.01	66%	188	89%	93%
mean	1.49	24.43	55%	163.31	74%	83%
st dev	0.22	2.21	9%	18.51	12%	8%
min	1.07	20.42	36%	115.00	47%	64%
max	2.10	29.27	77%	194.00	95%	97%

APPENDIX F

SYNOPOSIS OF STUDY

Synopsis of Study

The Accuracy of Polar "OwnCal" in Estimating Energy Expenditure during Aerobic Dance Bench Stepping

1. Participants (n~30) will be recruiting from students enrolled in Physical Fitness and Wellness classes offered during Fall 2008 at Texas State University. Typically students are between the ages 18 to 29 years.
2. This study is intended for apparently healthy adults exhibiting no signs or symptoms suggestive of heart, metabolic (diabetes), and pulmonary disease. To identity who should not participate in the study, a comprehensive health-history survey will be administered to identify volunteers who: 1) have heart disease, diabetes, chronic obstructive pulmonary disease (including asthma) 2) have experience recent musculoskeletal injuries, and 3) are pregnant (or think they are pregnant).
3. At the beginning of the Fall semester, the primary investigator will inform potential participants in enrolled in the PFW's classes about the components of the study. Interested participants will be instructed to sign up for an initial visit to the lab. They will be given pre-test instructions instructing them, prior to each lab visit, to abstrain:1) from food and beverages for 1 to 2 hours, 2) tobacco products for 3 hours, and 3) alcohol and caffeine for 48 hours. During the first visit, participants will be given a consent form to read, be given the opportunity to ask questions about the

study, and will be asked to sign the consent form if they would like to proceed with participation in to the study.

4. Each participant will visit the laboratory on 3 different occasions. During visit # 1, participants will: 1) sign the consent form, 2) complete a health appraisal, 3) be measured for height and weight, and 4) be measured for aerobic fitness. During the second and third visits participants will be fitted with a heart rate monitor and mouthpiece (connected to a metabolic cart) and, then, asked to follow a 20 min video-taped aerobic dance bench stepping routine.
5. The potential risks for the study are minimal. The most common risks during exercise testing are delayed onset muscle soreness and/or fatigue. Although there has been no research identifying a college-aged student's risk of death during graded maximal exercise, the studies on the risk of death during graded maximal exercise for middle-aged men is 1 death per 10,000 tests. In rare cases, people experience heart attack, stroke, or death during exercise. Every effort will be made to ensure that the participants are safe. We will let them know that if they experience a very fast heart rate, very slow heart rate, a pounding sensation in their chest, chest pain, pain in the arms, dizziness, or difficulty breathing, to stop exercising and notify the test administrator immediately. The test administrator will contact 911 if needed. It is important to note that the intensity and duration of the exercises, other than the maximal testing, that will be used in this study are no greater than that employed during typical group exercise (e.g., aerobic dance bench stepping) classes. During

exercise, it is normal for heart rate and breathing rate to increase and for sweating to occur.

To ensure participant's safety, the following statement will be included in the consent form: "This study is intended for apparently healthy female adults exhibiting no signs or symptoms suggestive of heart, metabolic (diabetes), and pulmonary disease. If you have been diagnosed with heart disease, diabetes, and chronic obstructive pulmonary disease (including severe asthma) , have recently experienced a musculoskeletal injury, have been told by a health care provider to not exercise, or are pregnant (or think that you might be pregnant), then you should not participate in the study. "

6. As mentioned in previous items, volunteers will be completely informed of the risks. In addition, the consent form will instruct volunteers to not participate in the study if they "have been diagnosed with heart disease, diabetes, and chronic obstructive pulmonary disease (including severe asthma), have recently experienced a musculoskeletal injury, have been told by a health care provider to not exercise, or are pregnant (or think they might be pregnant)." The health history form is explicit and requires that volunteers answer whether they have been told by a doctor that they have a heart problem, suffer chest pain, experience dizziness or fainting, have a history of joint or bone problems, take or have been advised to take medication for heart or blood pressure conditions or have any other physical conditions that might impair safety.

As mentioned in item #4, at each testing, It will be advise to participants that if they experience a very fast heart rate, very slow heart rate, a pounding sensation in their chest, chest pain, pain in the arms, dizziness, or difficulty breathing, they are to stop exercising and notify the test administrator immediately. The test administrator will contact 911 if needed.

In order to minimize potential risk, each participant is able to withdraw from this study at anytime without any consequences to her course grade. In addition to having self control over termination, other safety measures will be implemented: 1) the aerobics instructor (i.e., the primary investigator) is certified in CPR, 2) the testing room is in close proximity to the athletic training offices, and 3) the building houses an automated external defibrillator unit.

All participants' personal information will be kept confidential. Data will be kept in a locked cabinet in Dr. Lisa Lloyd's office. Dr Lloyd (Chair of thesis committee) and Annie Lowe (thesis student) will use this information for research, but the participant's name will not be given out in any reports.

7. Participants in the study will be provided with knowledge about the testing procedures and about how to carry out a scientific experiment. The results of this experiment will provide each student with the knowledge regarding the accuracy of the Polar F6 heart rate monitor in estimating energy expenditure, as well as there own current fitness level.
8. Participants will be offered extra credit as an incentive. An alternative opportunity for students who are not interested in participating in the study will be offered.

Participants will receive an extra 10 points to their total participation points out of 100 possible. The study is limited to female volunteers, but male volunteers will be able to receive extra credit by volunteering to help with the testing process.

9. As previously stated, the risks associated with this proposal are minimal, while the potential benefits are great. In short, the risk/benefit ratio greatly favors the potential benefits for not only the scientific community, but also to the participants, themselves, and anyone who wears a Polar F6 heart rate monitor while exercising. The investigators envision, as a result of this research, a better understanding of the accuracy of the Polar F6 heart rate monitor in estimating energy expenditure, during aerobic dance bench stepping.
10. This study will be conducted in the Human Performance laboratory. It has been approved by Dr. Lloyd, who is the director of the Human Performance Laboratory and the Chair of Annie Lowe (the primary investigator of this study) thesis committee.
11. This project is being conducted for my thesis. My Committee Chair is Dr. Lisa Lloyd, Interim Chair and associate professor in the Department of health, Physical Education, and Recreation Department. She can be reached at (512)-245 – 8358. Other committee members include: Dr. Kevin McCurdy and Dr. Michelle Pope, the Department of Health, Physical Education, and Recreation.
12. This proposed investigation has the approval of the members of my thesis committee: Drs. Lloyd, McCurdy, and Pope.

VITA

Annie Lynne Lowe was born in Phoenix, Arizona, on August 29, 1985, the daughter of Donna Lynne Lowe and David Ray Lowe. After completing her work at Denton High School, Denton, Texas, in 2003, she entered Texas State University-San Marcos. She received her degree of Bachelor of Science in Exercise Science from Texas State in December 2006. In January 2007, she began work at Texas State University-San Marcos as a Graduate Assistant.

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This thesis was typed by Annie L. Lowe.