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RESEARCH ARTICLE

Assessment and Prediction of Energy Expenditure: One-Mile Walks and Runs Among African American

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ABSTRACT

Among ethnicities, African Americans exhibit the highest prevalence of obesity. A more comprehensive grasp of energy expenditure while walking and running can be instrumental in managing and averting obesity. Regrettably, there is a scarcity of research dedicated to scrutinizing energy expenditure in African Americans during walking and running. Consequently, the primary objective of this study was to contrast energy expenditure disparities during a one-mile walk and run between African Americans of normal-weight and those classified as overweight. Additionally, the secondary aim was to formulate and validate a predictive equation for energy expenditure tailored specifically to African Americans. A total of 68 African American participants were involved in this study, comprising 21 individuals classified as normal-weight walkers, 27 as overweight walkers, and 20 as runners. Energy expenditure was assessed using indirect calorimetry. To compare energy expenditure across these groups, an Analysis of Variance (ANOVA) was conducted, followed by a post hoc Scheffe test. Linear regression analysis was employed for predicting energy expenditure. Additionally, a dependent *t*-test and a Chow test were utilized for cross-validating the predictive equation. The findings revealed that runners exhibited significantly higher energy expenditure compared to normal-weight walkers. When energy expenditure was normalized to body weight, runners expended significantly more energy than both normal-weight and overweight walkers. However, when expressed relative to fat-free mass, normal-weight walkers expended less energy than runners and overweight walkers. A prediction equation tailored specifically for African Americans was formulated as follows: EE = 1.012 BW − 9.233 Gender (M = 1, F = 2) + 47.188. The results from cross-validation tests confirmed the validity of this equation. Consequently, we recommend the use of this energy expenditure prediction equation for calculating energy expenditure during one-mile walks or runs for African American adults, whether they fall within the normal-weight or overweight categories.

Keywords: Cross-validation, normal-weight, overweight, prediction equation.

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1. Introduction

From 2017 to March 2020, the age-adjusted prevalence of obesity is 41.9% among American adults (Stierman *et al*., 2021). For African Americans, this prevalence ranks the top among all ethnicities (49.9%) (CDC, 2022). Obesity is designated as a disease and stands as a predominant comorbidity for other health conditions, including cardiovascular diseases and cancer. In 2019, the United States incurred an annual medical cost of nearly $173 billion directly related to obesity, as reported by the CDC (2022). This financial burden not only impacts individual health but also places a considerable economic strain on our government and society as a whole.

Physical activity serves as the primary avenue for expending energy to manage weight. Yet, it's observed that African Americans engage in less physical activity compared to their Caucasian counterparts (DiPietro & Caspersen, 1991). According to the American College of Sports Medicine guidelines, adults should aim to expend a minimum of 1000 kcal per week to uphold their health. Worryingly, only 41.8% of African Americans meet this recommendation (Haskell *et al*., 2007). This underscores the urgent need for increased physical activity to address and mitigate the alarming prevalence of obesity within the African American community.

Walking, a widely embraced and easily accessible physical activity, and running, which ranks among the top six preferred physical activities or exercises for Americans (Stephens *et al*., 1985), offer substantial benefits. These activities are not only convenient but also carry a lower risk of injury (Hu *et al*., 1999). Research has revealed that vigorous walking can lead to a reduction in body weight primarily through a decrease in body fat, with some concurrent gain in lean tissue, even without dietary intervention (Leon *et al*., 1979). Efforts to assess energy expenditure (EE) during walking and running are invaluable for exercise program designers. These assessments enable a thorough understanding of the level of physical activity required for weight loss or obesity prevention.

Various methods have been employed to measure EE, encompassing direct measurements, self-reported questionnaires, bioelectrical impedance, doubly labeled water, and user-friendly devices like pedometers (Levine, 2005). However, these approaches often involve high equipment costs and skilled testers, making them less accessible. In response to this challenge, a practical and user-friendly solution, the predicted EE equation, has gained acceptance among clinicians and the public for calculating EE. It's worth noting that most prediction equations primarily focus on resting EE, neglecting EE during physical activity, and their applicability across diverse ethnic groups can be limited due to subject variability (Vander Weg *et al*., 2004; Weijs, 2008). Notably, an EE prediction equation for Caucasians was developed in 2010 (Loftin *et al*., 2010). While in 2021, a specific EE equation for Asians was established (Jin *et al*., 2021). However, there remains a significant gap in research when it comes to physical activity EE in African Americans and the development of EE prediction equations tailored to this population. Consequently, this study aims to evaluate and forecast EE during one-mile walks or runs in African American adults, both of normal-weight and those classified as overweight, filling a vital void in the understanding of energy expenditure within this demographic.

2. Methods

2.1. Participants

The study encompassed a total of sixty-eight African American participants, comprising 25 males and 43 females. Participants were categorized into three groups based on their body fat percentages (Deurenberg *et al*., 1998). Specifically, there were 21 individuals in the normal-weight walking group (NWW), with body fat percentages below 22% for males and below 35% for females. The overweight walking group (OW) comprised 27 subjects with body fat percentages equal to or greater than 22% for males and 35% for females. Additionally, a running group (R) included 20 participants. Given that all runners were within the normal-weight range, there was no further division based on weight category.

It's important to note that all participants in the study were regular walkers or runners, meaning they engaged in walking or running activities for at least 30 minutes per session and at least three times a week. Ethical considerations were a top priority, with this research having received approval from the Institutional Review Board committee at the University of Mississippi for the use of human subjects. Furthermore, prior to participating in the study, each participant provided informed consent by signing a consent form.

2.2. Procedure

Before the EE test, participants underwent a series of baseline assessments to establish a resting foundation, which included measurements of body height and body weight, as well as a dual-energy X-ray absorptiometry scan to determine body composition. To ensure a consistent and standardized approach, participants were acquainted with the operation of the treadmill and determined their preferred walking and running speeds. These preferred speeds were in line with previous research conducted by other researchers in our laboratory (Loftin *et al*., 2010; Morris *et al*., 2014).

The actual test commenced with a brief three-minute warm-up period, after which participants engaged in either walking or running on the treadmill at their self-selected paces for a five-minute duration. The measurement of EE during the final two minutes of walking and running was accomplished through indirect calorimetry, utilizing parameters such as oxygen uptake and respiratory exchange ratio. The EE data were expressed in various units, including absolute units (kilocalories), kilocalories relative to body mass ($kcalmile^{-1}kgBW^{-1}$), and kilocalories relative to fat-free mass (FFM, $kcalmile^{-1}kgFFW^{-1}$). Additional comprehensive details about the experiment were published elsewhere (Jin *et al*., 2021).

3. Statistical Analyses

The data were represented as means along with their respective standard errors, and the statistical analyses were performed utilizing SPSS software (Version 24, SPSS, Inc., Chicago, IL). To compare the EE across the normal-weight walking group, overweight walking group, and running group, an Analysis of Variance (ANOVA) was employed, followed by a post hoc Scheffe test for further examination of the results.

In this study, participants were assigned to two groups through a random selection process. In the first group, 42 African American individuals, constituting 62% of the total sample, were utilized to develop a predictive equation for estimating energy expenditure (EE) during a one-mile walks or runs. The remaining 26 participants, comprising 38% of the total sample, were designated for the purpose of cross-validating the derived predictive equation. The cross-validation group represented 62% of the subjects in the validation phase.

Linear regression served as the methodology for constructing the EE prediction equation tailored to African Americans. Subsequently, two distinct approaches were applied to cross-validate the predictive EE equation: the dependent *t*-test and the Chow test. The dependent *t*-test was employed to assess the disparities between the actual measured EE and the predicted EE within the cross-validation group. Meanwhile, the Chow test was conducted to compare the regression coefficients derived from the cross-validation group equation with those of the original predictive equation. Statistical significance was established at an alpha level of 0.05 for all analyses.

4. Results

4.1. *Physical Characteristics and Energy Expenditure in African Americans*

The outcomes detailed in Table I pertain to the physical characteristics and EE among African American participants during one-mile walks or runs. As anticipated, noteworthy distinctions were observed in body weight, fat percentage, and fat mass. Additionally, the height of individuals in the OW group was significantly greater compared to those in the NWW and R groups. Moreover, the R group demonstrated a significantly swifter preferred speed compared to the other two groups.

In terms of EE during one-mile walks or runs among African Americans, the NWW group exhibited notably lower energy expenditure than the R group at their respective preferred walking or running paces. Another substantial disparity emerged between the OW and R groups when EE was expressed relative to body weight. Furthermore, when EE was expressed relative to fat-free mass (FFM), it was evident that normal-weight walkers expended significantly less energy compared to overweight walkers and runners.

4.2. *Predictive Equation for One-Mile Walks or Runs in African Americans and Its Cross-Validation*

A discernible correlation emerged between body weight and EE during one-mile walks or runs in African Americans, irrespective of their group affiliation (correlation coefficient, $r = 0.763$; coefficient of determination, $R^2 = 0.582$). Employing linear regression analysis to forecast EE in kilocalories, the following equation was derived for African Americans: EE = 1.012 BW − 9.233 Gender (M = 1, F = 2) + 47.188. The standard error of estimate (SEE) for this equation was determined to be 14.6 $\text{kcal}\cdot\text{mile}^{-1}$. This predictive model offers valuable insights into the EE associated with one-mile walking or running in the African American population and is crucial for better understanding and managing physical activity and its impact on energy expenditure.

Relying on the previously established equation (EE = 1.012 BW − 9.233 Gender (M = 1, F = 2) + 47.188), the predicted EE was calculated based on body weight and gender. A thorough comparison between the measured EE and the predicted EE was executed using a dependent *t*-test, and the results, as presented in Table II, demonstrated no significant difference between these two groups ($p > 0.05$).

By leveraging data from the cross-validation group, a new regression equation (EE = 1.246 BW − 14.770 Gender (M = 1, F = 2) + 41.133) was derived, enabling a comparison of the coefficients with the originally predicted equation (EE = 1.012 BW − 9.233 Gender (M = 1, F = 2) + 47.188). In this comparison, it was observed that the coefficient for body weight was 1.246 in the cross-validation group, in contrast to 1.012 in the initial predicted equation, while the coefficient for gender was −14.770 in the cross-validation group, differing from the −9.233 in the predicted equation. The constant was found to be 41.133 in the cross-validation group, deviating from the 47.188 in the predicted equation. The application of the Chow test, designed to assess differences in coefficients between these two equations, yielded a non-significant result, indicating that there were no significant variations in the coefficients associated with body weight and gender ($p = 0.636$). Fig. 1 provides a visual representation of the predicted values derived from the original predicted equation and the cross-validation equation,

TABLE I: Physical Characteristics and EE in Three Groups of African Americans

Variable	Group	Mean	SE	Min	Max
Age (year)	NWW	20.9	0.2	19	23
	OW	22.6	0.9	19	39
	R	21.4	0.4	19	26
BW (kg)	NWW	71.6^a	3.4	44.8	100.4
	OW	87.7^b	2.4	58	114.5
	R	72.7^a	3.4	47.2	104.9
Height (m)	NWW	1.7	0.02	1.5	1.9
	OW	1.6	0.02	1.5	1.9
	R	1.7	0.02	1.6	1.8
%Fat	NWW	19.8^a	1.4	9.7	30
	OW	35.6^b	1.0	25.4	44.5
	R	21.4^a	1.7	8.4	35
Preferred speed	NWW	3.4^a	0.08	2.6	4.0
	OW	3.4^a	0.08	2.4	4.1
	R	7.0^b	0.29	5.0	9.5
FM (kg)	NWW	13.7^a	1.1	5.8	21.8
	OW	29.7^b	1.4	19.6	49.4
	R	15.3^a	1.5	6.0	27.8
FFM (kg)	NWW	56.5	3.0	32.9	76.3
	OW	53.5	1.6	37.1	69.8
	R	56.0	2.8	37.6	83.1
$kcal{\cdot}mile^{-1}$	NWW	98.5^a	4.7	53.9	148.8
	OW	115.5	3.7	67.2	154.4
	R	119.0^b	6.8	69.2	183.8
$kcal{\cdot}mile^{-1}kgBW^{-1}$	NWW	1.4^a	0.04	1.0	1.7
	OW	1.4^a	0.03	1.0	1.7
	R	1.6^b	0.04	1.4	2.2
$kcal{\cdot}mile^{-1}kgFFM^{-1}$	NWW	1.8^a	0.06	1.2	2.2
	OW	2.2^b	0.06	1.6	2.7
	R	2.1^b	0.06	1.7	2.7

Note: Different letters (a, b, or c) indicate significant differences ($p < 0.05$) between groups. The same letter indicates no significant differences between groups.

TABLE II: Energy Expenditure in Cross-validation Group

Variable	Mean	SD	Min	Max
Measured $kcal{\cdot}mile^{-1}$	112.5	5.7	53.9	183.8
Predicted $kcal{\cdot}mile^{-1}$	109.6	3.7	74.1	144.1

illustrating their close alignment with the values corresponding to body weight. This concordance underscores the robustness and reliability of the predictive model.

5. Discussion

This study conducted a comprehensive analysis of EE among African American individuals categorized as normal-weight and overweight walkers, as well as runners. To provide a tailored solution for this population, a specific EE prediction equation was formulated, considering body weight and gender ($EE = 1.012\ BW - 9.233\ Gender\ (M = 1, F = 2) + 47.188$). The rigorous assessment encompassed both dependent *t*-tests and Chow tests, both of which lent support to the validation and reliability of this equation.

In this study, it was expected that among African American participants, the OW group exhibited significantly higher body weight, fat percentage, and fat mass compared to the NWW and R groups. The selection criteria for individuals classified as overweight were based on their fat percentages, which were at or above 22% for males and 35% for females. Therefore, it is not surprising that both their fat percentage and fat mass in the OW group surpassed those of the other two groups. Table I also revealed that there were comparable values for FFM among the different groups. Hence, the additional mass in the OW group primarily originated from fat mass or adipose tissue. It is apparent that a higher fat percentage and greater fat mass contributed to the overall increase in body weight, aligning with previous research findings that observed higher body weight and fat mass in overweight Caucasians (Loftin *et al.*, 2010).

Collectively, the EE of African Americans in this study exceeded 110 kcal·mile^{-1}, surpassing the EE observed in both Caucasians and Asians, as reported in a prior study (Jin *et al*., 2021). This finding underscores a unique energy profile in African American individuals. When examining absolute EE, it was observed that normal-weight walkers expended less energy than runners when covering one mile, which deviates from observations in Caucasians, such as those reported in the study of Loftin *et al*. (2010), which found no significant difference between normal-weight walkers and runners. This variance can be attributed to the biomechanical differences between walking and running. Walking, characterized by a straighter limb posture, demands less muscular force generation, resulting in a lower energy cost (Farley & McMahon, 1992).

Moreover, when body weight was factored into the analysis, disparities between normal-weight walkers and runners persisted, and new differences emerged between overweight walkers and runners. The strong correlation (r = 0.763) between body weight and EE further emphasizes the role of body mass in the expenditure of energy. Specifically, the overweight walkers exhibited significantly higher body weight compared to runners (as shown in Table I), confirming that greater body mass incurs higher energy costs. This association is consistent with the results of Loftin *et al*. (2010), which elucidated how added weight, whether natural or artificial, contributes to elevated EE.

Furthermore, when considering EE in relation to FFM, which represents metabolically active tissue, it was observed that the NWW group exhibited lower EE compared to the R or OW groups. Notably, there were no significant differences in FFM among the three groups; however, fat mass in the NWW group was lower compared to the OW group (as indicated in Table I). Fat mass is relatively metabolically inert but plays a role in regulating carbohydrate and fat metabolism processes. Consequently, when fat mass is greater, basal metabolic needs increase, which could account for the lower EE observed in the NWW group compared to the R or OW groups, a phenomenon in line with findings in 2009 (Woodruff *et al*., 2009).

In clinical practice, the precise measurement of EE during exercise assumes paramount importance, given that physical activity interventions represent a highly effective tool for managing body weight. Moreover, the development of an EE equation holds great significance, as it equips clinicians with a convenient means of predicting EE when prescribing exercise regimens based on easily accessible variables such as body weight or gender.

The current study offers African Americans a valuable tool for estimating their EE during one-mile walks or runs, with the equation relying on body weight and gender as key determinants. This approach empowers individuals to gain a deeper understanding of their energy balance, allowing for more effective planning of energy costs. The results of the study, including the dependent *t*-test, which revealed no significant difference between measured EE and predicted values in the cross-validation group, as well as the Chow test outcomes, which found no significant discrepancies between the coefficients of the predicted and cross-validation equations, affirm the validity and reliability of the derived EE prediction equation. Fig. 1 further underscores this validation by illustrating the striking similarity in the regression slopes between the predicted equation and the cross-validation equation.

In light of these findings, it is highly recommended that this EE prediction equation be embraced as a valuable tool in guiding training programs for one-mile walks or runs among African American

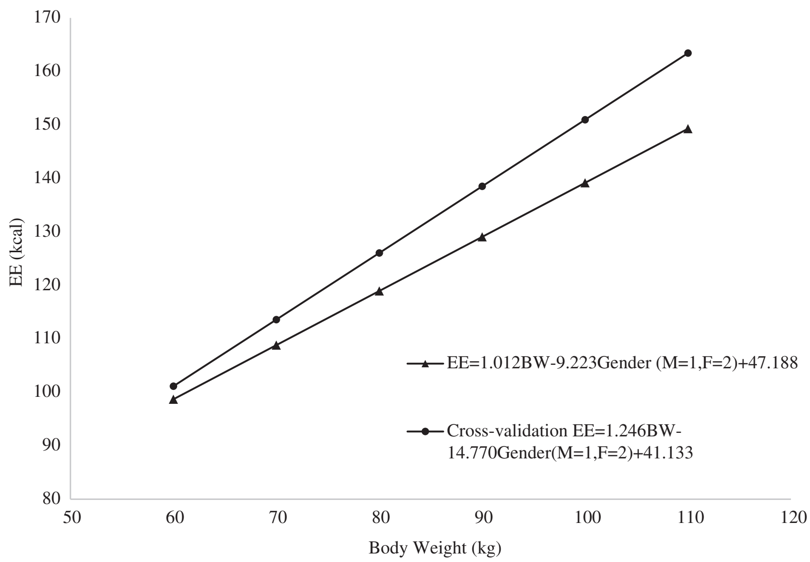

Fig. 1. Prediction of EE (kilocalories) by body weight (kilograms) in African Americans.

individuals, both those classified as normal-weight and those classified as overweight. This equation promises to be instrumental in promoting better health and fitness outcomes for this population.

6. Strength and Limitations

This study marks a pioneering effort in the field, being the first to develop a dedicated EE equation for one-mile walks or runs tailored specifically to African American adults, encompassing both those with normal weight and those categorized as overweight. The equation's reliance on easily accessible variables, namely body weight and gender, makes it a highly convenient tool for estimating EE within the African American population.

However, it's imperative to acknowledge certain limitations. The study's sample size, though valuable for initial insights, may not be extensive enough to formulate an equation representative of the entire African American population. As such, further research is warranted to expand the sample size and enhance the equation's applicability. Furthermore, the EE equation developed in this study is primarily designed for walking or running activities. Future investigations could extend this predictive framework to encompass a broader spectrum of exercise types, including swimming and various ball games, ensuring a more comprehensive understanding of EE across diverse physical activities. These avenues for future research offer the potential to enhance the applicability and versatility of EE prediction equations in the context of exercise and health management.

7. Conclusion

This study diligently scrutinized EE during one-mile walks or runs within the African American community, covering both normal-weight and overweight individuals. The findings were conveyed through multiple metrics, including absolute EE, EE relative to body weight, and EE relative to FFM. Significantly, a tailored EE prediction equation specifically calibrated for African Americans was formulated and validated through two rigorous cross-validation assessments. As a result of this thorough investigation, we firmly recommend the utilization of this validated equation to accurately predict EE in African Americans engaging in one-mile walks or runs. This prediction tool stands to benefit both individuals and healthcare practitioners in their efforts to design effective exercise regimens, promote health and fitness, and manage weight within the African American population.

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Conflict of Interest

The authors declare that they do not have any conflict of interest.

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