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RESEARCH ARTICLE

Are NCAA Division-I Women's and Men's Cross-Country Runners Competing in the Same Race? A Physiological Perspective

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Abstract

A recent petition to transition Women's and Men's Divisions National Collegiate Athletic Association (NCAA) Division-I cross-country (XC) championships to a common distance of 8-km has been denied. This decision was made without access to published, quantitative assessments comparing the metabolic profiles of runners at their current, respective race distances.This study examined the magnitude of metabolic discrepancies between female (n=14) and male (n=17) runners at previous season personal best (PB) pace for conference championship race distances (female 5-km; 19.27 ± 0.89 min and male 8-km; 26.12 ± 1.23 min). Treadmill grade was set at 1% while metabolic variables were collected via indirect calorimetry and averaged for minutes 4 and 5 during a run at PB pace. Significant differences (p< 0.05) were found between female and male runners for percentage of 60 s $\dot{V}O_{2peak}$ (96.8 ± 5.5% vs 88.6 ± 7.5%) and respiratory exchange ratio (RER) (1.03 ± 0.06 vs 0.99 ± 0.04), respectively. Data were further analyzed within sex by comparing the fastest and slowest half runners. Despite ~7% difference in PB, highest and lowest half performers did not differ from each other for fractional utilization or RER at PB. It is not surprising that metabolic profiles differed between sexes however, these marked differences suggest that Men's and Women's Division runners are competing in physiologically distinct events. This evidence should be given consideration in decision making for future NCAA XC championship race distance selection.

Keywords: Respiratory Exchange Ratio, VO_{2peak}, Fractional Utilization, Gender, Sex, Title IX.

1. Introduction

A variety of personal attributes such as reactive strength index and leg stiffness (Barnes *et al.*, 2014, Dellagrana *et al.*, 2015, Li *et al.*, 2021) and external factors such as shoe mass and drafting strategies (Hoogkamer *et al.*, 2017) play a role in distance running performance. However, a combination of aerobic capacity, running economy, and ability to enhance lactate tolerance are widely believed to dictate the majority contributions to endurance running performance (Joyner, 1991). Without consideration of psychological factors, each runner hypothetically has a maximal pace at which performance can be maintained depending on the distance of the event, course characteristics, and metabolic profile of the competitor. The pace that can be maintained for long distance running events has traditionally been termed as the *anaerobic threshold* or more contemporarily as *maximal metabolic steady state* (Jones *et al.*, 2019). The methods and measurements used to determine maximal metabolic steady state are both nuanced and numerous with examples such as critical power (Moritani *et al.*, 1981), maximal lactate steady state (Bang, 1936, Heck *et al.*, 1985), and lactate turnpoint (Davis *et al.*, 1983). The validity and interchangeability of these terms and methods continues to be debated (Jones *et al.*, 2019, Dotan, 2022). Regardless, for performance capacity it

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is helpful to have an understanding and description of the athlete's physiological status at competition pace. Classic studies have examined cardiorespiratory profiles of long-distance runners (Costill, 1969, Costill *et al.*, 1973, Maughan and Leiper, 1983), but few investigations have examined metabolic status at the same race distance between sexes. Davies and Thompson (1979) reported that male (81.9 ± 3.2% of $\dot{V}O_{2max}$) and female (78.7 ± 6.6% of $\dot{V}O_{2max}$) marathon runners compete at similar fractional utilizations of aerobic capacity, despite vast differences in finishing time. Essentially, the race distance but not duration, dictated the maximal metabolic steady state that runners competed at regardless of sex.

National Collegiate Athletics Association (NCAA) cross-country (XC) has continued to gain popularity, with 13,489 male and 14,122 female athletes participating in the 2021 season across all divisions (NCAA, 2021b). However, the current authors are unaware of similar attempts to compare Women's versus Men's Division competitors' metabolic profiles at personal best (PB) race pace. A unique challenge is presented in comparing NCAA XC metabolic profiles at PB between Men's and Women's Divisions because they do not compete at equal distances for their conference, regional, or national meets. Both support and critique have been made for continuation of this traditional practice (Huber, 2021, Wisner, 2022), and a recent petition to alter XC championship race distances to 8-km for both Men's and Women's Divisions was recently rejected by the NCAA (Equal Distance.org, 2022). With different race distances being used to determine individual champions and team championships, the question arises, are Women's and Men's division NCAA XC runners competing in similar events from a physiological basis?

NCAA XC teams typically consist of 12 or more runners, but a team's score is determined by totaling the fastest five runners' individual finishing scores (NCAA, 2021a). During the regular season, NCAA XC Women's and Men'steams often compete at 5-km and 8-km distances, respectively. Many conferences also use the 5-km (Women's Division) and 8-km (Men's Division) distances for their conference championships. Over the 7-9-week XC season ample opportunities exist for runners to determine their PB performance at these distances. It is intuitive to assume races of different distances will produce altered physiological artifacts regardless of runners' sex, but the degree to which current XC race distances differ needs to be elucidated. The primary purpose of this investigation was to define and compare the metabolic profiles of NCAA Division-I XC runners at their previous season PB for their respective common and conference championship distances. Furthermore, additional comparison efforts were made to determine if metabolic profile variables differed between slower and faster competitors or were correlated with PB within Women's and Men's Divisions' teams' respective cohorts. We hypothesized that the metabolic profiles of each division would differ not only in statistical significance, but that the magnitude of key variables' differences would indicate that Women's and Men's Division runners are competing in markedly unique events.

2. Materials and Methods

2.1 Participants

Runners in the current study were intended to be representative of a typical, competitive mid-major level caliber NCAA Division-I XC team roster in terms of academic classification and performance capacity. Investigators recruited runners from two different NCAA Division-I universities before formal practices with permission from each team's head coach. An *a priori* power analysis (G*Power 3.1.9.6, Kiel, Germany) was conducted with a difference in fractional utilization between sexes of 5% and a standard deviation of 5% for each group defined as a meaningful difference criterion between male and female cohorts. Using an alpha of 0.05 and beta of 0.80, an n of 17 was required for each group. Fourteen female and seventeen male XC runners were successfully recruited after their season was finished and participated in all tasks required in the current study. All participants were 18 years of age or older. Age for female and male participants were 19.6 ± 1.4 and 19.6 ± 1.7 years, respectively. There were 4 female and 7 male freshmen; 3 female and 4 male sophomores; 4 female and 3 male juniors; and 3 seniors for both male and female cohorts. In addition, one school won their conference championship for both teams. The other university teams both finished in the bottom half of their conference championship meet. The two universities' runners competed in different NCAA Division-I conferences, but both schools' conference championship races were 5-km (Women's Division) and 8-km (Men's Division), respectively. All participants had passed physician directed physicals and pre-activity screening questionnaires. Runners provided written consent before data collection and study procedures were approved by local institutional review boards at each data collection site. This study conformed with guidelines in accordance with the Declaration of Helsinki.

2.2 Experimental Protocol

Height to the nearest cm (females = 162 ± 9 cm; male = 178 ± 3 cm) and body mass to the nearest 0.1 kg (female = 54.6 ± 3.8 kg; male = 65.0 ± 5.0 kg) were determined during the initial visit to the laboratory using a digital scale (BWB-800, Tanita Inc. Tokyo, Japan) and stadiometer (Invicta Plastics Limited, Leicster, England). Runners then completed their normal warm-up routine before being fitted with a soft malleable facemask (V2 Facemask, Cosmed, Rome, Italy) and heart rate monitor (Polar Electro, Kempele, Finland) for a graded exercise test (Sharp *et al.*, 2022). Treadmill speed began 2.4 km/h slower than the participant's estimated 5-km pace rounded to the nearest 0.8 km/h and 0% grade. Treadmill speed was increased by 0.8 km/h every 2 min until volitional fatigue while oxygen consumption ($\dot{V}O_2$) was measured by indirect calorimetry (True One 2400, Parvo Medics Inc. Provo, Utah).We considered the highest 60-s average during the final 2 min of $\dot{V}O_2$ testing as the participant's $\dot{V}O_{2peak60}$. This value was used for fractional utilization purposes. Standard manufacturer's procedures were followed for flowmeter calibration and 2-point gas concentration calibration. A description of participants is provided in Table 1.

Table 1. *Description of metabolic profile variables for Women's and Men's Division NCAA Division-I cross-country runners at personal best (PB) pace from previous season (mean ± SD (min-max)).*

	Women (5-km Distance; n = 14)	**Men (8-km Distance; n = 17)**
PB (min)	19.27 ± 0.89 (17.80-21.33)	26.12 ± 1.23 (23.87-28.52)
PB (km/h)	15.8 ± 0.8 (14.0-17.5)	18.4 ± 0.89 (16.9-20.1)
$VO_{2peak60}$ (ml/kg/min)	53.5 ± 2.8 (48.1-59.1)	68.4 ± 4.1 (61.8-75.9)
$VO_{2peak60}$ (L/min)	2.94 ± 0.29 (2.47-3.70)	4.42 ± 0.40 (3.49-4.96)
	Metabolic profile at PB pace	
VO_2 (L/min)	2.84 ± 0.32 (2.45-3.71)	3.90 ± 0.35 (3.32-4.43)
% of $VO_{2peak60}$*	96.8 ± 5.5 (82.7-104.7)†	88.6 ± 7.5 (76.5-100.8)
VCO_2 (L/min)	2.91 ± 0.39 (2.19-3.75)	3.83 ± 0.41 (3.17-4.63)
RER*	1.03 ± 0.06 (0.89-1.11)†	0.99 ± 0.04 (0.93-1.05)
Heart rate (beats/min)*	181 ± 11 (164-204)	179 ± 11 (157-196)
Respiratory rate (breaths/min)*	47 ± 9 (32-63)	41 ± 14 (26-69)

Only * variables were statistically analyzed because sex-based physiological or race distance differences did not allow for valid between sex comparisons. † = $p < 0.05$ versus men.

On a subsequent visit to the laboratories, participants were asked to recall their PB time for 8-km (male runners) and 5-km (female runners) races from the previous season. Following a self-selected warm-up, participants commenced the running protocol. Treadmill (4 Front, Woodway, Waukesha, WI) pace for the metabolic profile data collection bout was set to match PB rounded to the nearest 0.16 km/h, and the treadmill grade was set to 1% to match air resistance experienced during outdoor running (Jones and Doust, 1996). The PB running bout was designed to last 5 min with absolute $\dot{V}O_2$ assessed in 60-s averages. Although the intensity for some runners was likely to produce an intensity that would cause respiratory exchange ratio (RER) to exceed 1.00, confirmation of *steady state* was operationally defined as an absolute change in $\dot{V}O_2$ of less than 0.1 L/min (Fletcher *et al.*, 2009) between min 4 and min 5. If greater than 0.1 L/min change was detected, participants continued for 1 more min (i.e. 6 min total). The values of min 4 and 5 (or min 4, 5, and 6 if steady state not reached at 5 min) were averaged and used for all metabolic profile variables. Heart rate was recorded in the last 15-s of min 4 and min 5, then averaged for data analysis purposes.

2.2.1 Statistical Analysis

Descriptive data including minimum, maximum, mean, and standard deviation were calculated for Men's and Women's Divisions data. Independent *t* tests were used to explore possible differences between female and male runners' heart rate, respiratory rate, RER, and percentage of $\dot{V}O_{2peak60}$ characteristics at PB pace for each sex's respective race distance. Independent *t* tests were also incorporated to compare metabolic profile variables between the fastest half and slowest half of runners by sex. Levene's test of homogeneity was incorporated to determine if variance between groups was acceptable, and degrees of freedom values were adjusted if necessary. Bivariate linear correlation was used to determine if metabolic profile variables were related to PB performance. All data analyses were conducted using SPSS v. 26.0 (IBM Co., Chicago, IL). An alpha level was set at 0.05 to be deemed significant *a priori*.

3. Results

Table 1 displays female and male data for all participants. The high intensity at which the XC runners competed at is exemplified by over half (10 female runners, 6 male runners) of participants' RER values exceeding 1.00. RER values and percentage of $\dot{V}O_{2peak60}$ were both higher in female runners, but heart rate and respiratory rate did not differ between sexes (Table 1). Average finish times for the fastest half runners were approximately 1:15 and 2:00 faster than the slowest half runners in Women's and Men's Divisions, respectively (Table 2).

Table 2. *Comparison of metabolic profile variables between top half and bottom half performers based on personal best (PB) pace from previous season (mean ± SD).*

	Women (5-km Distance)		Men (8-km Distance)	
	Slowest (n = 7)	Fastest (n = 7)	Slowest (n = 9)	Fastest (n = 8)
Body mass (kg)	55.4 ± 3.5	54.1 ± 4.1	66.9 ± 3.7†	62.2 ± 5.4
PB (min)	19.87 ± 0.77†	18.66 ± 0.51	27.08 ± 0.79†	25.05 ± 0.50
PB (km/h)	15.34 ± 0.70†	16.26 ± 0.71	17.69 ± 0.53†	19.16 ± 0.41
$VO_{2peak60}$ (ml/kg/min)	52.9 ± 3.6	54.2 ± 1.7	66.9 ± 2.4	70.1 ± 5.0
	Metabolic profile at PB pace			
% of $VO_{2peak60}$	96.4 ± 6.9	97.3 ± 4.5	86.4 ± 8.1	91.1 ± 6.4
RER	1.00 ± 0.07	1.05 ± 0.04	0.99 ± 0.03	0.99 ± 0.04
Heart rate (beats/min)	184 ± 13	178 ± 9	177 ± 12	181 ± 11
Respiratory rate (breaths/min)	46 ± 11	48 ± 9	39 ± 14	43 ± 15
† = $p < 0.05$ versus fastest half runners.				

Women's body mass and $\dot{V}O_{2peak60}$ were similar between faster and slower half runners, but the faster half Men's Division runners exhibited lower body mass and trended (p = 0.11) toward higher $VO_{2peak60}$ than the slower half runners (Table 2). Fractional utilization and RER were not related to PB for Women's or Men's Division runners (Table 3 & Figure 1).

Table 3. *Relationship between personal best (PB) performance and metabolic variables at PB pace (data displayed is r value).*

	% of $\dot{V}O_{2peak60}$	RER	Heart Rate (beats/min)	Respiratory Rate (breaths/min)
Women (n = 14)	0.29	-0.36	0.56†	-0.05
Men (n = 17)	-0.05	0.21	0.13	0.04
† = significant correlation ($p < 0.05$).				

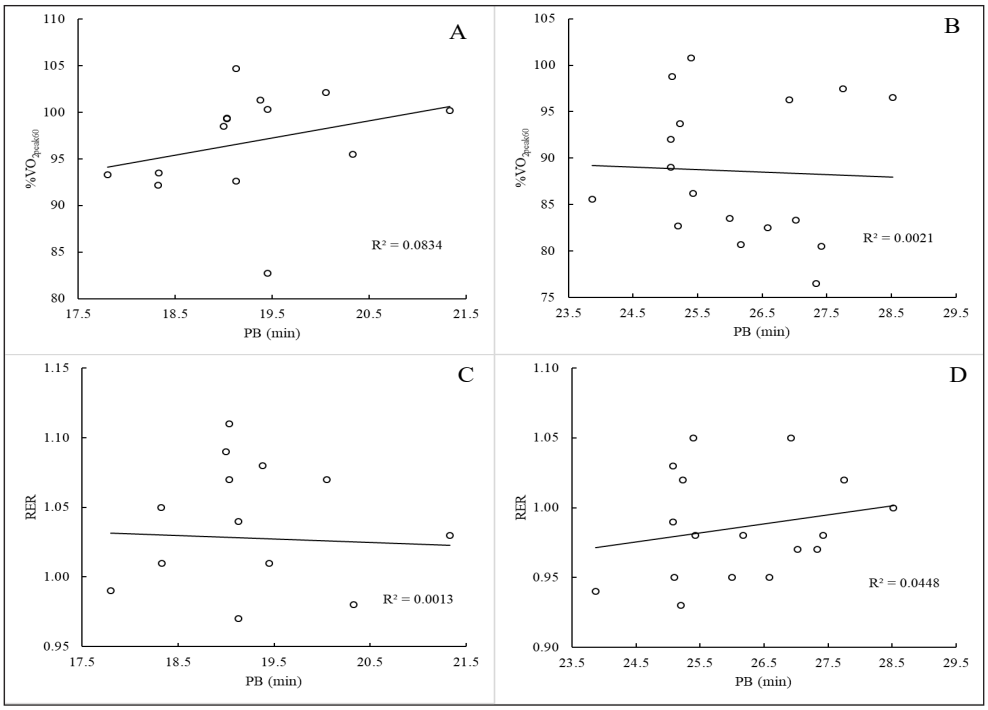

Figure 1. *Relationship between personal best finish time and fractional utilization and RER for female (A (p = 0.32) & C (p = 0.90)) and male (B (p = 0.86) & D (p = 0.42)) collegiate cross-country athletes.*

Heart rate for Women's Division runners was the only variable that displayed significant correlation with PB (Table 3).

4. Discussion

In August of 2022, the NCAA rejected a petition to make both the Men's and Women's Divisions XC championships 8-km in distance (Equal Distance.org, 2022). Discovery of this failed equidistance proposal in our literature review for a previous XC focused study (Carder *et al.*, At Press) stimulated our motivation to use a subset of data from the previous project to produce this paper. This study is not intended to conclusively support the traditional stance or advocate for change to equidistance, but to describe the physiological responses of Women's and Men's Division XC runners at their current competitive distance PB pace. The hope of the authors was to provide previously unavailable empirical evidence and data to NCAA leaders in future decision-making processes. It is critical to begin this discussion addressing the greatest limitation of this investigation. Testing a hypothesis to determine if male and female runners would compete at similar metabolic profiles for the 8-km equidistance advocated to the NCAA (Equal Distance.org, 2022) was not possible. This is not a comparison that could or should be made at this time. For the Women's Division, the most common regular season meet distance is 5-km, and NCAA Regional and National Championship Meets are 6-km distance. Women's Division XC team members in this study did not formally train for or compete at the 8-km distance. As such, this paper only examines the degree to which metabolic profiles of Men's and Women's Divisions' XC team runners differ at current, gender-based competition distances.

The first major, but not unexpected, finding of this study was that Men's (8-km) and Women's (5-km) XC divisions' respective conference competition distances yielded distinct metabolic profiles. Blood lactate concentration was not assessed as a component of our original study (Carder *et al.*, At Press). However, comparison of germane investigations suggests that the intensity at which Women's Division team members compete easily exceeds lactate threshold in as little as 5 min at PB pace. Fernhall *et al.* (1996) predicted lactate threshold (defined as 4 mmol/L) would occur at ~90% of $\dot{V}O_{2max}$ for high school XC runners. This finding was later supported and confirmed in trained 1,500 m runners by Jones and Tolfrey (2003). Moreover, Støa *et al.* (2010) reported mean lactate exceeded 6 mmol/L following 8 min of running at 5-km pace for internationally competitive male runners. RER (1.05 ± 0.04) values reported by Støa *et al.* (2010) were similar to that of our overall female runner values (Table 1) and identical to that of our fastest female XC runners (Table 2). Houmard *et al.* (1991) reported lactate of 5.0 ± 0.7 mmol/L at a submaximal running speed of 268 m/min in the fastest 7 malerunners for a XC team considerably slower (conference championship 8-km race average >29 min) than runners in the current study. Undoubtedly, the average Women's Division XC runner surpassed this threshold at PB pace, while the average Men's Division runner only approached this status (Tables 1 & 2). Furthermore, the single treadmill speed used by Houmard and colleagues (1991) was slower than that used by our male runners, but elicited the same mean fractional utilization of 88%. These data suggest that Men's Division XC runners competing at 8-km distance pace, will exceed lactate threshold, but collectively past studies and our present findings support that lactate accumulation is less severe and/or exceeds threshold levels traditionally considered of importance later in competition compared to Women's Division XC runners.

There are several caveats that should be noted in relation to fractional utilization profiles and comparisons. The highest 60-s $\dot{V}O_2$ value in the final 2 min of the graded exercise test (i.e. $\dot{V}O_{2peak60}$) was used in calculation of fractional utilization for this study. From a validation standpoint, $\dot{V}O_{2peak60}$ as opposed to $\dot{V}O_{2max}$ was chosen for multiple reasons. Many individuals are incapable of demonstrating the plateau required for $\dot{V}O_{2max}$ confirmation (Niemeyer *et al.*, 2021). This lack of a plateau is even more common in incremental protocols like the one used in this study versus single intensity testing protocols. However, as demonstrated by Day *et al.* (2003), incremental and continuous protocols do not produce different values for $\dot{V}O_{2peak}$ versus a plateau-based $\dot{V}O_{2max}$ if the same sampling interval is used. Furthermore, short sampling intervals inflate $\dot{V}O_{2max}$ and $\dot{V}O_{2peak}$ and should be a consideration in fractional utilization comparisons (Hill *et al.*, 2003, Scheadler *et al.*, 2017). For example, a study using a 15-s sampling interval would likely produce a higher $\dot{V}O_{2peak}$, resulting in lower fractional utilization than was reported in the current study. Using $\dot{V}O_{2peak60}$ also allowed more direct comparisons to the whole min averages we used for PB pace cardiorespiratory data. Finally, while our operational definition of steady state (i.e. $\dot{V}O_2$ difference of less than 0.1 L/min) was met for nearly every runner, the intensity during the 5 min running bouts likely exceeded that of what is

traditionally considered a pace capable of exhibiting maximal metabolic steady state.

With these considerations and previous points of contention concerning race intensity in relation to lactate threshold, it is difficult to interpret the magnitude of 8.2% difference of fractional utilization between male and female runners as arbitrary. Molinari *et al.* (2020) examined male 3-km competitors simulating race competition while wearing a portable metabolic system. Their observations were that the mean time in which $\dot{V}O_2$ was equal to or greater than the runners' $\dot{V}O_{2max}$ was over 50%, and time spent above $\dot{V}O_{2max}$ was a strong predictor of finishing time (r = 0.86). We are unaware of data concerning similar analysis to that of Molinari, Edwards and Billat (2020) in female running populations at any race distance. However, the average Women's Division runners in the current study were approaching their $\dot{V}O_{2peak60}$ in a time span equaling 20-25% of average race duration. The current study only provides the fractional utilization of $\dot{V}O_{2peak60}$ at race pace, not the time spent at $\dot{V}O_{2max}$ as in Molinari, Edwards and Billat (2020), but unlike those male 3-km competitors, neither $\%\dot{V}O_{2peak60}$ or RER at PB was related to performance in the current study (Table3; Figure 1).

Weston *et al.* (2000) performed one of the few investigations in which fractional utilization and RER were compared across two groups of runners competing in distances closer to that of our male runners. Eight African and eight Caucasian male, running club 10-km competitors with similar group means for PB were compared using an almost identical design to the current study. Despite having higher $\dot{V}O_{2peak}$, the Caucasian runners' fractional utilization of their $\dot{V}O_{2peak}$ was 6.2% lower (92.2 ± 3.7% vs 86.0 ± 4.8%) than their African counter parts of similar skill level and yet, both groups displayed identical RER values (0.99). These outcomes are strikingly similar in comparison to the fastest versus slowest Men's Division runners' data in the current study. All four means and statistical outcomes are almost identical to those in the current study, with the exception that fractional utilization trended toward (p = 0.21) but did not reach statistical significance (Table 2). The splitting of runners from these two schools essentially represented team members that would likely have scoreable performances over the season versus those that would not on a typical 14 plus member XC squad. Essentially, if there were physiological differences between that fastest and slowest half runners within each division, arguing that Men's and Women's XC Divisions were competing in different events would be a more difficult position to defend. As in the current study's comparison between slower and faster runners in the same cohort, it is likely Weston *et al.* (2000) suffered from low statistical power. However, the authors postulated fractional utilization differences between ethnicities might be explained by alterations in expression of Kreb's cycle enzymes discovered in previous work from their laboratory, leading to improved running economy (Weston *et al.*, 1999). It is plausible genetic predisposition and running economy advantages akin to faster runners also likely explain the lack of difference but trend toward higher fractional utilization among higher performing male runners. Still, identical RER and lack of statistical difference of fractional utilization between faster and slower Men's Division runners further supports metabolic homogeneity of 8-km intensity across skill level and within sex.

Fractional utilization did not differ between faster and slower Women's Division runners, but there was a trend toward higher RER in the faster female runners (p = 0.14). However, further examination of individual data in Figure 1C suggest this tendency towards mean differences is likely an artifact of small sample size, as there was a very weak relationship between PB and RER. While some slower Women's Division runners did exhibit higher RER values, 3 of the 4 lowest RERs belonged to runners in the slower half in contrast to 3 of the 4 highest RERs belonging to the fastest group, likely skewing comparison of mean data. Individual data displayed in Figure 1 scatterplots highlight the vast potential heterogeneity of metabolic profile exhibited by runners at race PB and inability of PB fractional utilization or RER to predict performance capacity. Such great variance and unpredictability should make it more difficult to differentiate between Men's and Women's Division runners, but this was not the case.The unambiguous mean increasesin both RER and fractional utilization in combination for female runners makes a strong argument for these race distances to be considered physiologically unique events. In essence, the fastest and slowest competitors within each race distance were not metabolically distinguishable from each other, but male and female runners competing at their respective XC race distances display markedly unique metabolic signatures.

5. Conclusion

This is the first investigation we are aware of in which metabolic profiles at PB data have been presented for Women's or Men's Divisions XC runners. There are

many factors beyond the scope of the current paper that need to be evaluated as the NCAA considers the future competition distances to be used in XC regional and national championship meets. However, this study demonstrates that Men's and Women's NCAA Division-I XC runners currently compete at race distances producing distinct metabolic profiles that are not explained by within sex performance capacity. If races are united to one distance for Men's and Women's divisions in the future, these factors can easily be re-examined with 8-km PB data. In the near term, comparisons of similar skill level (e.g. multiple runners from the same conference) NCAA Outdoor Track and Field 5,000 m and 10,000 m competitors could be explored to determine if Men's and Women's Divisions runners exhibit similar metabolic characteristics when training for and competing at the same race distances.

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Declaration of Interest

This project received no external funding. The authors declare no conflict of interest.

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