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Are Females Better Adapted for Ultrarunning Than Males? - A Literature Review

Bachelor's thesis in Human Movement Science
Supervisor: Jørgen Danielsen
May 2023

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Abstract

The gender gap in ultrarunning is smaller compared to shorter running distances. Factors such as muscle composition, neuromuscular fatigue, and substrate utilization has been suggested as factors that contribute to this trend. In this systematic literature review, the databases PubMed and SportDiscus was used to gather literature. This article aims to explore why females reduce the performance differences compared to males. The results are that females tend to have a higher proportion of fatigue-resistant Type I muscle fibers and demonstrate better preservation of strength and resistance to neuromuscular fatigue during ultrarunning races. Females also utilize more fat oxidation, providing a metabolic advantage with a more developed ability to utilize myocellular triacylglycerol. Understanding these physiological factors can promote females' unique physiological structure and gather knowledge about female performance. Further research is needed on ultrarunners to explore specific mechanisms underlying the performance similarities between males and females, developing evidence–based guidelines for the field. Keywords in this review: Ultrarunning, Sex Difference and Physiological.

Sammendrag

Kjønnsforskjellen ved ultraløp er mindre sammenlignet med kortere distanser. Faktorer som muskelsammensetning, nevromuskulær tretthet og substratutnyttelse har blitt foreslått som faktorer som bidrar til denne trenden. I denne systematiske litteraturgjennomgangen ble databasene PubMed og SportDiscus brukt for å samle litteratur. Denne artikkelen går ut på å utforske hvorfor kvinner reduserer prestasjonsforskjellene sammenlignet med menn. Resultatene viser at kvinner har en tendens til å ha en høyere andel tretthetsresistente Type I muskelfibre og viser bedre bevaring av styrke og motstand mot nevromuskulær tretthet under ultraløp. Kvinner utnytter fettoksidasjon bedre, noe som gir en metabolsk fordel med en mer utviklet evne til å utnytte myocellulær triacylglycerol. Å forstå disse fysiologiske faktorene kan fremme kvinners unike fysiologiske struktur og samle kunnskap om kvinners prestasjoner. Videre forskning er nødvendig på ultraløpere for å utforske spesifikke mekanismer som ligger til grunn for prestasjonsforskjellene mellom menn og kvinner, og utvikle evidensbaserte retningslinjer for feltet. Nøkkelord i denne rapporten: Ultraløping, Kjønnsforskjeller og Fysiologisk.

1. Introduction

1.1 Ultrarunning as A Concept

Running is often referred to as the worlds easiest sport to participate in, and all one need is a pair of joggers and some suitable clothing. It is possible to compete in all kinds of distances. Some people will push their limits to the extreme with competing in running races beyond the traditional marathon distance (42,195 meter), also called ultramarathons. Traditional ultramarathon distances are 50 km, 50 miles, 100 km and 100 miles, or time limited races with the most common races being 6h, 12h, 24h and 48h. The terrain which competed on varies into a high degree, from flat asphalt to mountain races and trail races. The competitiveness is rapidly increasing in the sport, with increasing participations and full-time elite athletes in ultrarunning, both for males and females. Females counts for 23% of all participations in ultrarunning event by 2020. There has been a considerable increase in the past 23 years, when it was just 14% females participation in ultrarunning races (1).

1.2 Sex Differences in Ultrarunning

The performance difference (average speed, average power) between males and females in various sports are well studied and documented. For sprint- (100m - 400m), middle- (600m - 3000m) and long- (5000m - marathon) distance running events, a review study from Sandbakk et al (2017) found that the average gender gap is 10-12% (2). Though, for the two most common ultramarathon distances 50-miles and 100-miles, the gender gap is found to be respectively 9,1% and 4,4% when collecting data from all participations in the database of German Society for Ultra-Marathon (Deutsche Ultramarathon Vereinigung) (3). Another study found the gender gap to be 3,7% for 50-miles and 0,3% for 100-miles. The same study even further found that females outperform males in races >195 miles with 0,6% for all participations over multiple years (1). A study on 24h races between 1977 to 2012 found that when all competitors were included, the gender gap was just 4.6±0.5% (4).

This decreasing gender gap with increasing race distances implies that there must be some underlaying factors that applies or make a smaller difference in ultrarunning than in other sports.

The known factors, such that males have a higher $\dot{V}O_2max$, more muscle mass and more testosterone than females, make a generally consistent gender gap in most power and endurance sports. The aforementioned factors will either don't have the same impact in ultrarunning as in other sports or other factors that confer the female endurance body will have a counteractive effect on the gender gap.

1.3 Goal of the Review

The purpose of this systemic review is to study the following question: why does females decrease the performance differences to males in ultrarunning, compared to shorter running distances? It is a vacancy on this topic, that a systemic review can fill with an adequate overview of the gender gap in ultrarunning. In addition, with a growing concern regarding transgender participations in females' sports, where in some cases they demolish the other contestants, make it essential to create an evidence-based guide to include transgender persons in ultrarunning, making the sport more open and fairer for all, which this review can help to make.

2. Method

The literature search was conducted between January and April 2023. For acquisition of literature, the scientific databases PubMed and SportDiscus were used, where a systemic review of available studies on topic was performed. To accumulate the desired studies, the keywords used are shown in Table 1. To be included, all studies had to have the keywords in Title/Abstract, be performed on humans, as well as it needed to be at least seven participants of each gender. Studies performed on older adults and children were excluded. More exclusion criteria were studies who only separated between slow twitch fibers and fast twitch fibers, and not Type I-, Type IIa- and Type IIx- fibers. Additionally, studies performed on animals, and studies performed on athletes competing in sports without an endurance factor such as weightlifting e.g., where excluded. As well as studies on other ultra-endurance sports were excluded because of a focus on sports specific factors that's not relevant for ultrarunning. In total, eight articles fulfilled the criteria and were included in this review. Furthermore, ten studies were included as supporting literature.

Table 1: Shows keywords used in the literature search with AND between the columns.

First Keyword	**Second Keyword**	**Third Keyword**
Ultramarathon	Sex Difference	Muscle Biopsy
OR	OR	OR
Ultrarunning	Gender Difference	Neuromuscular Fatigue
OR		OR
Ultra endurance		Substrate Utilization

3. Results

Staron et al (5) collected data over ten years and compared muscle fiber composition in the vastus lateralis between males and females. The subjects were a total of 150 healthy and untrained college-aged males and females, 95 males and 55 females. The subjects had a mean age of 21.5 ± 2.4 years (males) and 21.2 ± 2.2 years (females). The biopsies were between 80-160mg and were from the superficial portion of the vastus lateralis and extracted using the percutaneous needle biopsy technique. For a more accurate comparison, all samples were taken ~16 cm proximal to the superior border of the patella. The females were lower, lighter and had a higher percentage of body fat than the males included. All biopsy specimens, except four of the 150, contained more than 400 muscle fibers. Males had a greater cross-sectional area of the muscle. Females showed a greater percentage area of Type I fibers in biopsy of the vastus lateralis, with 44,0 ± 11,6% for females, against 36,2 ± 11,6% for males. For the percentage fiber type area occupied by Type IIa and Type IIx fibers were 41.2 ± 9.4% and 22.6 ± 11.8% for men, and 33.6 ± 8.7% and 22.4 ± 10.3% for females. In addition, the largest muscle fiber for each sex was different. For males the largest was Type IIa and for females the largest was Type I. In sum, Staron et al (5) found that females had a significantly higher cross-sectional area percentage of Type I fibers than males.

Yasuda et al (6) investigated sex differences in muscle function and morphology with a short-term limb immobilization. A total of 27 recreationally active adults were included, 13 males and 14 females. The mean age were 20.8 ± 1.9 years and 21.6 ± 2.6 years for males and females, respectively. The subjects were non-smokers, not injured the last 6 months, not highly trained and were not taking any medications regurlarly. Before the biopsy, the subjects refrained from exercise for 3 days, and were fasting overnight. A biopsy from vastus lateralis was taken with modified Bergström biopsy needle with manual suction. The incision was taken approximately 15 cm proximal to lateral joint space. After the biopsy was completed, the sample was cooled in liquid-nitrogen at -80º C. Males and females had a similar distribution of Type I fibers, 45.5 ± 10,6% for males and 47.8 ± 9.5% for females, it was neither found any statistically significant difference in Type IIa or Type IIx distribution between males and females. The percentages fiber type area for Type I and Type II (IIa + IIx) was found to be 31.4 ± 4.6% and 68.6 ± 4.6% for females, and 27.2 ± 3.3% and 72.8 ± 3.3% for males (p-value <0.05).

Fournier et al (7) compared muscle fiber composition in the semitendinosus muscle. The 24 subjects, 12 males and 12 females, were selected from the inclusion criteria of waiting for an ACL reconstruction by using semitendinosus and gracilis autograft and aged between 18 and 50 years. Mean age for males were 34 ± 8 years and 35 ± 8 years for females. The subjects had no prior hamstring injuries registered. The samples were collected using a close-ended tendon stripper, before the biopsies were frozen at -80ºC in liquid-nitrogen. The biopsies contained ~500 fibers per sample. Females had a greater percentage of Type I fibers (48.7 ± 8.9%, p-value < 0.05) than males (35.6 ± 10.1%). In contrast to this, males had 33.8 ± 5.7% and 33.9 ± 7.4% Type IIa and IIx, compared to females 31.3 ± 8.0% and 27.4 ± 7.4%, only the difference in Type IIx had a p-value <0.05. Males had generally larger muscle fibers than females, but the difference in size was bigger for Type IIa and IIx than Type I fibers. Succinate Dehydrogenase staining showed that females had a larger proportion of oxidative muscle fibers (49.3 ± 10.6%) compared to males (37.4 ± 11.2%) and a p-value < 0.05.

Temesi et al. (8) investigated neuromuscular fatigue (NMF) among 20 healthy and experienced, ultra trail runners, matched to each other by relative performance. Gender distribution among these were ten males and ten females with mean age 41 ± 10 and 44 ± 7, respectively. The study conducted the possible sex differences in neuromuscular fatigue in central and peripheral mechanisms. After a 110-kilometer ultra-trail race looking at neuromuscular fatigue in knee extensors (KE) and plantar flexors (PF). Within the evaluation of neuromuscular function, transcranial magnetic simulation (TMS) and an electrical nerve stimulation was conducted PRE and POST the 110-kilometer trail race. POST protocols were performed as soon as possible after completion of the race. PRE-race, females showed a maximum voluntarily contraction (MVC) in KE of 115 ± 27Nm, and 193 ± 31Nm in males (p-value <0.001). Considering PF, males had a result of 175 ± 26 and females had a result of 115 ± 18 (p-value <0.001). The results showed that maximal KE torque post-race, gave a gender difference (P = 0.006) in NMF, where MVC decreased more in males (-38%) than females (-29%). Testing the evoked mechanics PRE-POST-sex interactions, the plantar flexors showed a greater decline in potentiated twitch amplitude in males than females (-23% and -8%, respectively). Temesi et al. gives an adequate result considering the lower level of fatigue in KE and peripheral fatigue in PF.

Besson et al. (9) investigated sex differences in neuromuscular fatigue after mountain trail races, with distances ranging from 40km to 171km. 36 participants took part in the study, 18 males and 18 females, matched by performance in the different race distances. Notably, the races were divided into to two clusters, SHORT and LONG (<60 and >100km). The participants completed different races that varied in time, from hours to five days in Ultra-Trail du Mont-Blanc. Furthermore, neuromuscular function tests were conducted before and after the races and assessed in knee extensors and the plantar flexors, applying willingly and evoked contractions. The present study´s findings indicate that males and females experienced a comparable decrease in maximal torque during knee extension exercises. The study reported a sex difference of -40% in males, while females showed a decrease of -33%, but did not reach a statistically significant result (p-value = 0.051). Moreover, this study confirms that females experience less fatigue, shown by the lower decrease in the maximal strength in longer distances. Additionally, females also showed less peripheral fatigue in short distances, when compared to males (peak twitch; -10% in females and -24% in males (p-value <0.05). The article shows a gender difference in MEP_{AREA}, considering maximal isometric contractions at 100% target torque level, and gave a significant time-sex interaction in LONG ultrarunning distances in males (PRE, 40.2 ± 13.8; POST, 56.6 ± 13.9) and females (PRE, 42.5 ± 18.7; POST, 48.0 ± 18.8), resulting in a significant difference (p<0.05).

Maher et al (10) investigated the difference sex had on respiratory exchange ratio (RER) and fat oxidation. The subjects were 12 males and 11 females, with a mean age of 22 ± 2 years. Inclusive criteria were that they were healthy, non-smoking, non-obese and recreationally active. The tests were taken when cycling on 65% of $\dot{V}O_{2PEAK}$ for 90 minutes on a stationary electronically braked cycle ergometer, with constant pedaling cadence, and wattage was adjusted at each timepoint to ensure that the subject maintained the targeted $\dot{V}O_2$ uptake. For measuring RER, a computerized open circuit gas collection system was used, and measurements was taken as a mean from the time points from the 30- and 60-minutes recordings. The determination of fat and glucose oxidation rates, fat oxidation percentage and glucose utilized was done by non-protein respiratory quotient, and based on respiratory measurements from 10-15, 30-40 and 60-70 minutes. Females had a RER of 0.87 ± 0.02 and males had a mean of 0.91 ± 0.01 (p-value < 0.05). When looking at fat oxidation (%), the mean value for females was 45.0 ± 4.9% and 29.3 ± 3.5% for males (p-value < 0.05). Regarding glucose oxidation (%), females had a mean of 55.0 ± 4.9%, and for males the mean was 70.4 ± 3.5% (p-value < 0.05). No statistically significant difference was found for sex differences in g/min for fat oxidation. However, for glucose oxidation in g/min, a statistically significant difference occurred, where females' mean was 1.31 ± 0.12, and 2.36 ± 0.14 for males (p-value < 0.05). When comparing $\dot{V}O_{2PEAK}$ to fat free mass between sexes, no significant difference was found, although females (39 mL*kg bodyweight*min^{-1}) had a significantly lower $\dot{V}O_{2PEAK}$ than males (44 mL*kg bodyweight*min^{-1}). Maher et al. describes a greater FA transport capability of skeletal muscle in females, observing that females are more efficient at using lipid as a substrate during endurance physical activity compared to males.

Roepstorff et al. (11) analyzed the gender differences in substrate utilization, looking at the utilization of blood glucose, glycogen, plasma fatty acids (FA) and myocellular triacylglycerol (MCTG). From screening 48 young endurance trained males and females, they recruited seven males (mean age; 26 ± 1) and seven females (mean age; 25 ± 1). The participants endured an exercise test, cycling on a Krogh bicycle ergometer for 90 minutes, equivalent to 58% of $\dot{V}O_{2PEAK}$, where blood samples were collected from the femoral artery and vein at different times during exercise (15, 30, 60, 75 and 90 min). RER was similar in females (0.79 ± 0.02) and males (0.79 ± 0.02) (not significant (NS)). When exercise was initiated, RER increased in both genders (mean

0.89 ± 0.02 in females, 0.91 ± 0.01 in males; $p < 0.001$). Furthermore, a decrease in RER was noticed in the 60–90-minute interval (mean 0.87 ± 0.02 in females and 0.88 ± 0.01 in males; $p < 0.05$). No gender difference in RER was observed. At the final 60 minutes of the Krogh bicycle ergometer test, plasma FA was measured relative to lean leg mass (LLM), considering uptake, release, and oxidation. Plasma FA absolute uptake and oxidation showed no significant gender difference, but females had a higher total release of plasma FA (mean 15.1 ± 2.1 * kg LLM * min^{-1}) than males (4.6 ± 2.4 * kg LLM * min^{-1}), showing a significant gender difference (p-value < 0.001). MCTG provided 25.0 ± 6.0% to the oxidated metabolism in females, and 5.0 ± 7.3% in males. When looking at lipid utilization contribution, the contribution differed between females and males, 37.0 ± 6.4% and 14.6 ± 6.7%, respectively. The gender categorization among MCTG´s contribution to oxidative metabolism gave a significant difference in females and males (p-value < 0.05). Roepstorff et al. shows a greater plasma FA release in females, even though plasma FA oxidation were similar in males and females. Moreover, MCTG provided significantly more to the oxidated metabolism in females compared to males.

Steffensen et al (12) analyzed the usage of myocellular triacylglycerol (MCTG) during 90 minutes of submaximal exercise. 42 young, healthy, non-smoking subjects participated, 21 female and 21 male subjects categorized at three different training levels (untrained (UT), moderately trained (MT) and endurance trained (END)). Mean age for females in different training levels was UT 27 ± 1, for MT 26 ± 1 and for END 25 ± 1, and mean age for males was for UT 27 ± 2, for MT 23 ± 1 and for END 26 ± 1. The test was performed on a Krogh bicycle ergometer, determining $\dot{V}O_{2PEAK}$ (60%). MCTG storages presents a substantial energy source during prolonged exercise during conditions with a lower energy availability. Female subjects showed a significant amount in the utilization of MCTG, compared to males that showed no sign of utilization during physical activity (PA). The article considers evidence among the MCTG content in the vastus lateralis, regardless of training status. At a rested state, females showed 48.4 ± 4.2 for UT, 48.5 ± 8.4 for MT and 52.2 ± 5.8 mmol/kg wt% for END, ($p < 0.001$), and males (34.1 ± 4.9 for UT, 31.6 ± 3.3 for MT and 38.4 ± 3.0 mmol/kg wt% for END, ($p < 0.001$)). When starting exercise, a mean decrease of 25% ($p < 0.001$) was shown in females, while males results were persistently unchanged. Steffensen et al. gave significant evidence, that female subjects utilize and use MCTG, while males show no usage at all during prolonged exercise.

4. Discussion

Females have proven to decrease the gender gap to men in ultrarunning, even in some outstanding female performances where they have beaten the male winner in races. The goal of this review was to find the causes of the smaller gender gap in ultrarunning, compared to shorter running distances.

4.1 Effect of Sex Differences in Muscle Composition

Staron et al. (5) investigated muscle fiber composition in the vastus lateralis muscle. Males have a greater proportion of the faster Type IIA fibers, while females showed greater percentage fiber type area in the slower Type I fibers. Although, the three major muscle fiber types (I, IIA and IIx) is shown to be larger in the vastus lateralis of males, scientists report a higher percentage of Type I fibers in females. However, Yasuda et al. (6) found that females and males had a similar percentage distribution of Type I fibers, but females did show a greater Type I fiber percentage area in vastus lateralis supporting the findings of Staron et al. Also, within this study, males showed a greater percentage of Type II fibers, indicating that males are more suited for explosiveness and short power outputs. The categorization of the gender difference in fiber types may account for discrepancies in muscle endurance, because of continuous supply of oxygen to produce ATP to the muscle, hence it's better endurance, contra glycolytic fibers (Type IIx fibers) which create ATP in a anaerobic glycolysis (13). It must be acknowledged that the rich capillary supply and the high concentration of myoglobin in the Type I fibers, can function over extended periods of time and contributes to the observed female decrease of the gender gap of males in ultrarunning.

Moreover, the semitendinosus muscle also showed the same typological pattern in muscle fiber composition and illustrated a greater fatigue resistance in females. The semitendinosus muscle displays a faster phenotype in the hamstring among males and a higher percentage of ATPasepositive fiber, reactive to a specific acid pH (7). Males have considerably larger Type I fibers than females, but they accounted for a smaller percentage of the muscle. Within the muscle fiber composition of the semitendinosus, succinate dehydrogenase showed a larger proportion of oxidative muscle fibers in females than in males. These studies support each other's results, their evidence among the larger percentage area of Type I fibers in females. This might explain why females are more resistant to muscular fatigue. It should be mentioned, these findings represent the normative differences, and it is not clear if these results occur in elite and recreational ultrarunners. Although, they show a clear trend in the muscle compositions differences between the sexes that could indicate that females are better adapted to ultrarunning than males.

The practical implication of these differences in muscle composition can make females more suited to run at a slower pace over longer periods of time, as in ultrarunning, contra shorter distances where the pace is higher and where the properties of the slow muscle fibers are not at their best. Males on the other hand, have faster twitch muscle fibers that fatigue more quickly making males more suited for shorter distances with a faster pace where the endurance is not as important as in ultrarunning. In ultrarunning it's important to have the endurance to keep up the pace through the whole race.

4.2 Neuromuscular Fatigue Differences

The results from the articles considering neuromuscular fatigue, shows interesting results in fatigue among knee extensors (KE) and plantar flexors (PF) (8,9). Where females expressed less peripheral fatigue, and males showed a greater decrease in maximal force in KE after participating in a 110-km ultra-trail marathon (8). A possible explanation of the loss in KE maximum voluntary contraction (MVC) in males, is due to the several deficits in the central nervous system. Furthermore, there is a question considering the greater peripheral PF fatigue which may be explained by the reduced tendon compliance in males. Observations of the Achilles and patellar tendons concludes with greater stiffness in males. Interestingly, fascicle lengthening among males was especially contributable to the increase in tendon stiffness (9). Additionally, motor-evoked potentials (MEP), recorded with surface electrodes in specified muscles, showed a gender difference in the fatigue MEP_{AREA}, with an increase in male subjects. These results may explain why males experience a more extensive strength loss in KE than females. Reasons why this difference among genders occurs, might be explained by the increase of cortical output, appearing when limitations in neuromuscular function appears downstream of motor cortex.

The better resistance in neuromuscular fatigue in KE and PF in females, can be of importance when describing the decrease in gender gap because of during ultraruns one is at particular risk of injuries and pains in knees and ankles. Preserving the strength in the injury-prone areas will help one to avoid injuries and pain that force you to slow down the pace. Meanwhile, the less reduced KE and PF will contribute to stabilize the running and is a sign of greater stamina.

Besson et al. (9) reports a gender difference with a non-significant p-value of 0.051, and it can be speculated that with a larger selection, maximal torque during KE could have been a significant result. These results could explain why females perform better in ultrarunning distances, due to the observed lower levels of fatigue in knee extensors and peripheral fatigue in the plantar flexors. It should be taken into consideration that greater female participations in these studies could create more precise results and better understanding of the underlaying causes of the differences and its implications.

4.3 Utilization of Fat Versus Carbohydrates

Most ultrarunning races last for >6 hours. This brings with it the importance of being able to utilize the fat resources stored in the body, and not only having to rely on carbohydrates and nutrition you consume along the way. RER is the ratio between usage of carbohydrates and fat where 0.7 indicates that fat is the only source of energy utilized, and a value of 1.00 or above, only carbohydrates are utilized, a value between indicates that both fat and carbohydrates are used (14). Studies investigating the differences in RER between the sexes in a 90 minute cycling bout with a intensity of 58% and 65% of $\dot{V}O_{2PEAK}$, found one statistical significant difference in a lower RER of females, but the other did not find this difference statistical significant (10,11). The significant difference found in RER in Maher et al (10) could indicate a better female ability to exploit the fat resources within the body, because of the lower values, females can utilize more fat at the same relative intensity as the male counterparts. This was seen in fat oxidation (%) where females had a significantly higher percentages of 45.0 ± 4.9% contra males 29.3 ± 3.5%, where males showed greater reliance on glucose oxidation. This difference in substrate utilization can substantiate that the female endurance body are more suited for ultrarunning. In contrast, Roepstorff et al. (11) did not find a statistically significant difference on a similar study design, with the cycling test being performed at 58% of $\dot{V}O_{2PEAK}$ contra Maher et al at 65% of $\dot{V}O_{2PEAK}$. A potential reason behind Roepstorff et al. not finding the same difference in RER could be the fewer number of subjects of each sex, therefore further research is needed to conclude on the topic.

Gender differences in utilization of the various types of lipid sources did however, show up in Roepstorff et al. and Steffensen et al (12). Females showed a difference in utilization of plasma fatty acids (FA) and myocellular triacylglycerol (MCTG) across the leg, contributing to a substantial energy resource for females. During exercise, females released a substantially larger value of fatty acids in the leg than males did (11). Even though net uptake and oxidation of plasma FA did not show any significant gender difference, males released significantly less FA across the leg, suggesting that females make better use of fat released during exercise. Considering the usage of MCTG, females' utilization during exercise did vary compared to males (11,12). When exercising, females utilized MCTG and there was no such contribution in males, matched for the leg and the vastus lateralis muscle. Interestingly, Steffensen et al. (12) found no differences in MCTG usage in females, regardless of training levels. This can imply that females trained for ultrarunning, will have the same utilization of MCTG as the females in the studies. Moreover, females' ability to exploit the energy resources stored in the body may give them an advantage during prolonged exercise, such as in ultrarunning. Since it is essential to take in nutrition along the way in ultrarunning, and not only rely on nutrition already consumed. This ability can have great implications on performance, but it's unsure of the direct impact of the substrate utilization has on performance over prolonged exercise. Thus, it may lead to females don't have the need to take in as much nutrition during the race. This can minimize the risk of gastrointestinal distress and become nutrient depleted which will influence the performance.

4.4 Other Ultra Endurance Sports

The findings in this review would most likely be similar regarding other sports, where it is possible to compete at extreme distances, such as ultra-cycling where one study found no gender difference in races >200 miles (15), in Ironman triathlon where the difference is slightly less than 10% (16), and the sex difference in open-water ultra-distance swimming is decreased to 6-9%, proportional to the distance, varying from 5-25km (17). Many of the same physiological differences would apply in other sports such as females' higher percentages of Type I fibers, and better utilization of fat. This would be favorable in the ultra-distances of sports. These factors would apply to activities stretched over longer periods of time, were fatigue and running out of nutrients is a possibility.

4.5 Limitations and Further Research

One limitation this review is exposed to is the lack of studies conducted on ultrarunners, both at elite level and at recreational level. Therefore, studies on physiological differences between males and females who are not necessarily ultrarunners, have been used. Even though, the studies used in this review indicates some of the factors that applies on the decreased gender gap in ultrarunning. For a more adequate comparison on why females decrease the gender gap to males in ultrarunning compared to shorter running distances, more studies performed on ultrarunners needs to be conducted, both at elite level and recreational level. This review has focused on a select few mechanism that have been proposed to favor females in ultrarunning. Other factors could potentially also influence the gender gap (e.g., psychological factors, pacing strategies, oxygen utilization and running economy when fatigued). Due to it is mostly males that has been studying these issues, it is necessarily to take potential gender bias into consideration. Because of this, in future research, it is imperative to include female researchers to get a more adequate and nuanced research. This will again minimize the potential risk of gender bias.

The review on the gender gap in ultrarunning exposed a disagreement on how big the gender gap is in ultrarunning. As aforementioned the studies this review has used, found that the gender gap lies between 0-5% for 100-miles and 3-9% for 50-miles when all participations are studied. On the other hand, studies investigating the gender gap between the top performers such as annual fastest, 10 fastest and 100 fastest, and world records, record a gender gap between 5-27% in 50km, 100km and 200km races (18). This large gender gap can be assumed to come from a relatively small female elite field competing at these extreme distances, which can make a confounded impression of a bigger gender gap than what actually exist.

5. Conclusion

When investigating the causes of the gender gap decrease in ultrarunning, physiological factors such as the higher Type I fiber percentage area, lower RER, and better distribution of fat at submaximal exercise, the usage of myocellular triacylglycerol, and lower neuromuscular fatigue in females are some of the female factors that prefer the female endurance body over males. The use of studies performed on subjects who is not ultrarunners are a limitation, however, it shows a significant difference in male and female exercise physiology that most likely also appears in ultrarunners. To improve the knowledge on the factors on why the females are decreasing the gender gap in ultrarunning, there is a need for more research done on ultrarunners and the gender difference in ultrarunning.

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