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The Fair Inclusion of Intersex and Transgender Athletes based on Kinesiology, Physiology and Athlete Wellness

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Fair eligibility-requirements for intersex and transgender female athletes are sorely needed for Olympic competition. Those designated 46 XY DSD are usually judged to be intersex females at birth with Differences of Sexual Development (DSD), producing testosterone-creating testes instead of ovaries. Men who transition to female are defined as transgender women and have testosterone-creating testes. To quantify the role of testosterone, physics and kinesiology were applied to running, swimming, speed skating and rowing, to evaluate the female/male velocity ratio of Olympic Champions from 1980 through 2020/21 as driven by the relative lean-to-weight ratio of elite athletes. That velocity ratio now equals the relative lean-to-weight ratio of 90%. Since circulating testosterone drives the lean-to-weight ratio, higher testosterone gives men that 10% advantage over women. A definitive paper written when a limit of 10 nmol/L was used, concluded that 5 nmol/L was the lowest reasonable limit to impose, and then it was exceeded against Castor Semenya. Intersex athletes were born that way, suggesting that no limit or a limit of 10 nmol/L would be fair. Since transgender female athletes undergo therapy, 5 nmol/L might be achievable without medical or psychological side effects, instead of requiring transition before male puberty, which happens rarely.

Keywords: *intersex females, transgender females, testosterone limits, lean-to-weight ratio, gender inclusion*

Introduction

For 128 years, women have sought equity in Olympic competition. Although women were not allowed to compete in 1896, they began their Olympic journey in 1900. They began competition in swimming in 1912 and in athletics in 1928. Women have now earned equal representation in Olympic competition, compared to their male counterparts; but a major problem has emerged for two groups who identify as female athletes: those who were identified as female at birth but have had Differences of Sexual Development and those who were identified as men at birth but have transitioned to become female transgender athletes. There are few of these athletes but the need for fairness calls out loudly.

Fairness is fundamentally a subjective activity, but fairness is best achieved when it takes proper account of objective facts. We begin by identifying world record holders in various events and the advantageous physical traits which are admired and accepted. Physics and kinesiology are then applied to swimming, rowing, running and speedskating to identify the key physical traits that define the relative velocity ratio of elite female/male athletes and we compare the accuracy of

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using an evaluation based on those relative traits compared to the actual relative velocity ratios of Olympic champions.

We examine differences in sexual development especially for intersex female athletes. The relationship between testosterone and relative lean-to-weight ratio is covered. The history of some intersex and transgender athletes is examined as well as what happens when testosterone limitations are enforced. Unfortunately, implementation of testosterone reduction is shown to have serious physical and psychological side effects.

Based on this study, suggestions are made for dealing fairly with intersex and transgender female athletes who seek inclusion in the Olympics.

World Record Holders Who Were "Born That Way"

Although copyright laws make it difficult to include photos of the present or past world record holders that we are about to discuss, the reader can locate photos using Google or other similar online search engines.

Weight throwers are born with significant upper body and arm strength, allowing them to generate enough force to be successful. That strength is clearly visible in Valerie Adams (New Zealand) and Ryan Courser (USA), women's and men's shotput world record holders.

Carl Lewis (USA) in the long jump and Keni Harrison (USA) in the 60m hurdles possess the balanced strong lower leg, thigh and upper body strength needed to move their entire bodies upward.

Jamaican runners like Usain Bolt in the 100m and 200m are born with a combination of lean-to-weight ratio and fast-responding muscles, while living in an environment with the weather and nutrition to enhance those advantages, making them highly successful in sprint events. Sifan Hassan, world record holder in the women's 10k, is typical of African distance runners who are extremely slender and have very high oxygen turnover, because of growing up at altitude. To illustrate their success, for the last seven Olympic Games, covering 1996 through 2020 (actually held in 2021), African runners in the 5k and 10k runs for men and women have won at least one medal in all those 28 events, Wikipedia-Olympic athletics winners-men (2024) and, Wikipedia-Olympic athletics winners-women (2024). We do not see action taken to handicap them or the others mentioned above for the various physical attributes they were born with.

In the next section, we quantify the measurable physical attributes that correspond with success. Having that objective knowledge, the goal will be to suggest fair answers to the difficult questions of deciding under what conditions intersex female athletes who were born that way and transgender female athletes can compete.

Derivation of the Relative Performance of Male and Female Athletes

Physics and kinesiology are used to derive the velocity ratio for women/men involving elite athletes competing in rowing, swimming, running and speed skating, Stefani (2006, 2014). The following abbreviations are used.

v = velocity, Cr = cranking coefficient, e = efficiency, LBM = lean body mass
m = body mass, Cd = drag coefficient, Tr = training, LTW = lean to weight ratio

Rowing and Swimming

For rowing, the left side of (1) is the power that the rower applies to the water. The right side is the power with which the water pulls back on the boat due to drag, which affects the achievable velocity. In all the sports considered, training affects the amount of power the athlete can generate from LBM while efficiency affects how much of that generated power works to move the athlete forward.

$$\text{LBM x Tr x e x Cr} = v^3 \text{ x surface area}(m^{2/3}) \text{ x Cd x constants} \qquad (1)$$

Next, (1) is written separately for women and men and divided, resulting in the velocity ratio in (2), affected by the relative women/men lean-to-weight ratio LTW_W/LTW_M, training, efficiency, and other terms.

$$v_W/v_M = [(LTW_W/LTW_M)\,(Cr_W/Cr_M)]^{1/3}\,(m_W / m_M)^{1/9}\,[(Tr_W/Tr_M)\,(e_W/e_M)]^{1/3} \qquad (2)$$

For swimming, the left side of (3) is the power that the swimmer applies to the water, which differs from that of rowing because the swimmer is directly in the water. The right side of (3) is the power with which the water pulls back on the swimmer due to drag, which has the same form as for rowing in (1).

$$\text{LBM x Tr x m x swim efficiency} = v^3 \text{ x surface area } (m^{2/3}) \text{ x Cd x constants} \qquad (3)$$

As was done in (2) for rowing, (4) for swimming provides the velocity ratio.

$$v_W/v_M = [(LTW_W/LTW_M)/(Cd_W/Cd_M)]^{1/3}(m_W / m_M)^{4/9}\,[(Tr_W/Tr_M)\,(e_W/e_M)]^{1/3} \qquad (4)$$

Equations (2) and (4) can be simplified using a data base of 2286 elite athletes, taken from 10 papers used in Stefani (2014). The cranking (arm pulling) ratio, Cr_W/Cr_M, and the drag ratio, Cd_W/Cd_M, both are found to closely equal the relative LTW ratio, while the mass ratio, closely equals the square of the relative LTW ratio. By using those equalities to simplify (2) and (4), as shown in the top panel of Table 1, surprisingly, the velocity ratios for rowing and swimming are the same in terms of the relative LTW, relative training and relative efficiency.

Table 1. *The Velocity Ratio of Elite Rowers, Swimmers, Runners, and Speed Skaters in Terms of Relative Lean-to-Weight Ratio, Relative Training, and Relative Efficiency*

Sport	**v_W/v_M**	
	Lean-to-Weight	**Training and Efficiency**
Rowing and Swimming	$(LTW_W/LTW_M)^{8/9}$	$[(Tr_W/Tr_M)(e_W/e_M)]^{1/3}$
Running and Speed Skating	LTW_W/LTW_M	$(Tr_W/Tr_M)(e_W/e_M)$

Running and Speed Skating

The physics and kinesiology of running and speed skating both involve applying power to the ground to move against gravity as evaluated on the left of (5) while gravity pulls back, creating the right side of (5), affecting achievable velocity. By writing (5) for women and for men and then dividing and simplifying, we have the result in the lower panel of Table 1.

$$\text{LBM x training x efficiency} = \text{m x velocity x f(angles)} \qquad (5)$$

The four sports are remarkably similar, all strongly affected by the relative lean-to-weight ratio. If training and efficiency are about the same for women and men, the relative lean-to-weight ratio would determine the velocity ratio. We now examine the average velocity ratio of female/male Olympic champions as compared to elite athlete values for LTW_W/LTW_M in Table 2 for rowing and swimming and in Table 3 for running and speed skating.

Lean- to-Weight Ratios and Velocity Ratios for Olympic Campions

Five periods of Olympic history are chosen for Tables 2 and 3, starting when women first competed in swimming in 1912. These periods separately include the dominating effects and recovery from WW1, WW2, the cold war, boycotting, and the current administration of anti-drug policies. The average velocity for the female and male Olympic champions of each era are calculated from winning times taken from the International Olympic Committee website. The velocity ratios are compared with available relative LTW ratios as per Table 1, from the sources in Stefani (2014).

In Table 2 for swimming, the female Olympic champions have increased their relative velocity ratio until we see equality in the most recent two periods with the 8/9 power of relative LTW. For rowing, we obtain the same values for the most recent period as for swimming: 90% relative velocity ratio and 90% predicted by the 8/9 power of relative LTW. That means women have achieved equity in terms of training and efficiency and that relative LTW is the main physiological determinant.

Table 2. *Rowing and Swimming Comparisons of the 8/9 Power of Elite Athlete LTW Values with the Velocity Ratios of Olympic Champions*

	Rowing		Swimming	
Period	**Elite LTW %Ratios N=1789**	**Rowing Champions Velocity %Ratios N=49**	**Elite LTW %Ratios N=1815**	**Swim Champions Velocity %Ratios N=181**
1912-1924 (WW1)				83
1928-1952 (WW2)				87
1956-1976 (Cold War)				90
1980-1988 (Boycotts)		90	91	91
1992-2021 (Anti-Drug)	90	90	90	90

In speed skating, the female Olympic champions' relative velocity increased until it was the same as relative LTW in the fourth period used. For running, women also improved their relative velocity ratio but for the most recent two periods their relative velocity ratios are each 1% lower than what we would expect based on relative LTW. As explained in Stefani (2014), there is a known inefficiency for women because their hip width relative to their height is wider than for men, creating a longer stride, probably causing the 1% inefficiency. Women have 6 times the ACL tears as men, likely the cumulative effect of those longer strides relative to height. We have seen women undergoing knee strengthening exercises, during visits to the Colorado Springs Olympic Training Centre.

Table 3. *Running and Speed Skating Comparisons of Elite Athlete LTW Values to the Velocity Ratios of Olympic Champions*

	Running		Speed Skating	
Period	**Elite LTW Ratios N=156**	**Running Champions Velocity %Ratios N=103**	**Elite LTW Ratios N=51**	**Speed Skating Champions Velocity %Ratios N=46**
1912-1924 (WW1)				
1928-1952 (WW2)		88		
1956-1976 (Cold War)		89		**89**
1980-1988 (Boycotts)	**92**	**91**	**92**	**92**
1992-2022 (Anti-Drug)	**91**	**90**		**92**

The two conclusions from the four sports above are that women have made advances in training and efficiency, equalizing with their male counterparts and that relative LTW is the dominant effect of velocity differences with men. Now that women have made these gains and now that we have great world record holders who are born with obviously useful LTW ratios for their sports, issues have emerged with female athletes who were identified as female at birth but who have had differences of sexual development that they were just born with. We now examine differences of sexual development.

Differences of Sexual Development

Humans typically have 46 chromosomes, two of which denote sex, Medline Plus-Differences of Sexual Development (2024). A male with normal development has XY chromosomes and is identified as 46 XY having male genitalia and testes. A female with normal development has XX chromosomes and it identified as 46 XX having female genitalia and ovaries.

Table 4. *Normal Sexual Development and Differences of Sexual Development (DSD)*

Chromosomes	Description	Genitalia	Gonads
46 XY	Male	Male	Testes
46 XY DSD	**Intersex Female**	**Mostly Female**	**Testes**
46 XX	Female	Female	Ovaries
46 XX DSD	Intersex Male	Mostly Male	Ovaries

A male or female with differences of sexual development is identified as DSD in Table 4 and is referred to as intersex because the normal genitalia and gonads are switched. An intersex female (46 XY DSD) has genitalia that are mostly female at birth causing identification as a female, but instead of ovaries, the person has testosterone-producing testes. An intersex male (46 XX DSD) has genitalia that are mostly male at birth, causing identification as a male, but instead of testes, the person has ovaries. Testosterone-producing testes for the intersex female triggers a great deal of consideration because that person will have much more testosterone, and as we will learn, a higher LTW ratio than a 46 XX female. Conversely, there are no sports-competition issues with a 46 XX DSD male competing against normal males, because the intersex male lacks the testosterone that 46 XY males would have.

A famous case in sports history relates to Stella Walsh, whom we would now identify as being 46 XY DSD.

Stella Walsh

Born in Poland in 1911 as Stanislawa Walasiewic, her parents emigrated with her to the US when she was young. She used Stella Wash as her Americanized name. Information on her life is available at Wikipedia-Stella Walsh (2024). As she grew up, she exhibited skill in athletics. Photos taken during her sports career show a masculine appearance. Due to her status as an immigrant born in Poland, she was unable to find a way to become eligible to compete for the US. Competing for Poland, she won a gold medal at 100m in the 1932 LA Olympics and silver at 100m in the 1936 Berlin Olympics. After WW2, she was still unable to become eligible to compete for the US so her athletics career ended.

Walsh was shot and killed resisting an armed robbery in 1980. An autopsy showed that she had an incomplete uterus and a non-functioning, underdeveloped penis. Chromosome analysis revealed she was what we would now call 46 XY DSD, having testes instead of ovaries, implying significant testosterone creation.

Her birth record, stated that she was female. The Cuyahoga County coroner, Samuel Gerber, stated that Walsh was "socially, culturally and legally" a woman. The IOC and the IAAF sports federation chose not to take away medals. Their lack of such action indicates an opinion that she was just born that way and no action was called for.

Male and Female Testosterone Levels and Issues with Controlling Them

Before puberty, males and females have very similar levels of testosterone. Sports competition in that age bracket allows both sexes to compete together equally. After puberty, male testosterone increases 20 times as fast as for females. The relative lean-to-weight ratio rises for males. As circulating testosterone rate grows for males, so too does the rate of haemoglobin growth which provides increased oxygen flow, enhancing running and swimming skills. Several references dealing with biological processes indicate that the advantage for males in running rises to 10% and the advantage in jumping rises to 20%. Those figures are consistent with Tables 2 and 3, in that a female/male velocity ratio of about 90% implies a 10% male advantage. As for jumping, kinetic energy proportional to the square of velocity equals potential energy created by vertical jumping height, required for both the high jump and to create long jump distance. The square of .9 equals .81, indicating men jump 19% better, close to the 20% quoted.

A definitive 60-page paper with 185 references, includes extensive discussion of the above biological processes involved with testosterone growth, Handelman et al. (2018). The paper includes a summary of studies of 3754 healthy men and 2655 healthy women, which was used to calculate 95% confidence intervals for men and women for circulating testosterone.

Women: 0 to 1.70 nmol/L
Men: 7.7 to 29.4 nmol/L

The paper was sponsored by the IAAF. Action taken by the IAAF after publication, regarding limitation on intersex athletes like Castor Semenya as discussed below, shows reliance on these values. The paper suggests that the then practice of limiting intersex and transgender athletes to 10 nmol/L was not strict enough. Neither was using 7 nmol/L. Given that many exceptional female athletes have above 1.7 nmol/L for legitimate medical conditions, such as having ovarian cysts, the paper concluded that intersex and transgender female athletes should be limited to <5 nmol/L to compete fairly and yet not to disenfranchise female athletes with legitimate medical conditions.

Those figures are based on the survey of 95% confidence levels and not on the effects on athlete wellness. There are significant physical side effects due to reducing testosterone for intersex female athletes: Karkazis et al. (2012), and Karkazis and Carpenter (2018). There are also significant psychological side effects when the intersex female athlete must undergo embarrassing physical examinations and when her physicality becomes public as she seeks certification.

The papers point out that the intersex female was born that way, had sought no advantage and ought not to have experienced such an attack on wellness.

Next, we examine the experiences of a current-day intersex female athlete.

Caster Semenya

Caster Semenya was born in South Africa in 1991 and identified at birth as female, Wikipedia-Castor Semenya (2024). As a young female, she showed skill in athletics as did Stella Walsh years earlier. As was true of Walsh, Semenya showed a masculine appearance. She was designated as intersex, 46 XY DSD. The specific testosterone limits required of her clearly show the importance placed by the IAAF on Handleman et al. (2018).

From 2011 to 2018, as required by the IAAF for an intersex female athlete, Caster kept her testosterone level under 10 nmol/L, although she stated that the medications used to reduce testosterone made her feel ill. She won 6 medals in the world championships and Olympics (5 at 800m and 1 at 1500m).

From 2018 to 2023, the IAAF would not let intersex female athletes compete from 400m to 1 mile who were over 5 nmol/L, but they could compete at shorter or longer distances if their testosterone level was below 10 nmol/L. She could not comply with 5 nmol/L, so she tried 200m and 5000m but could not reach the finals.

From 2023, the IAAF requires intersex female athletes to be under 2.5 nmol/L for 2 years to compete from 400m to 1 mile and for 6 months for other events, even though Handleman et al. (2018) indicated that the limit ought not to be below 5 nmol/L. Her career was over, but she and other intersex female athletes were born that way but probably cannot reach 2.5 nmol/L without a gonadectomy.

Transgender Athletes

While limits on testosterone have been created for intersex female athletes, finding an objective method for including transgender female athletes has proven more difficult. The term sex refers to biology while gender refers to preference. A transgender athlete has one biological sex but choses to follow the opposite gender. A male transitioning to become a transgender female does have an advantage against biological females due to testosterone-induced physicality. The proactiveness now exhibited in sports against transgender female athletes can be traced back to the situation surrounding the Press Sisters.

Questions Raised by Irina and Tamara Press

The Press sisters were born in Ukraine of Jewish parents. They went on to compete for the Soviet Union. Tamara Press (1937-2021), Wikipedia-Tamara Press (2024), won 4 medals in the shot put and discus during the 1960 and 1964 Olympics. Irina Press (1939-2004), Wikipedia-Irina Press (2024), won 2 medals in the 80m hurdles and pentathlon during the 1960 and 1964 Olympics. Together, they set 27 world records. In competition, they appeared to be female; however, when traveling and in other contexts, they dressed and appeared to be brothers, as in the photo in TransGriot-Press Sisters (2024).

These sexual identity questions raised serious issues about the very credibility of female competition in world and Olympic competition. It was reasonable, under these circumstances, for the IAAF to create gender verification. Acting in haste, part of that verification involved the invasive and embarrassing inspection of the athlete. When it became required in 1966, the Press sisters both retired from sports competition. We do not know if they were being evasive about their sex or if they were simply insulted. All prior-to-1966 and future-to-1966 designations of Tamara and Irina Press have been that they were female.

In today's world, we would like transgender athletes to be dealt with fairly and compassionately, without creating problems with their mental wellness.

IOC Fairness Followed by Federation Exclusion

The complex and interrelated decisions for dealing with the Press sisters, Stella Walsh and Castor Semenya were part of a history of attempts to deal with sexual questions in sports, Wikipedia-Sex verification in sports (2023). Along with defining sexual identity have been attempts to restrict testosterone levels for intersex female athletes and transgender female athletes, Wikipedia-Testosterone regulations in women's athletics (2024).

Through 2015, the IOC had required gender-affirming surgery for transgender female athletes. In 2015, they terminated that practice, IOC (2015). In 2021, the IOC published a policy statement showing great compassion for transgender female athletes, IOC (2021). Included were efforts to promote inclusion, prevention of harm, non-discrimination, fairness, no presumption of advantage, an evidence-based approach, and primacy for health and bodily autonomy. Having opened the doors to compassion and fairness, the IOC then asked the sports federations to use those principles to create their own transgender policies.

Two federations basically slammed the doors shut on transgender females. Hearings were held by FINA, which renamed itself World Aquatics, and by IAAF, which renamed itself World Athletics. Policies were then activated by World Aquatics in June 2022, World Aquatics (2022), and by World Athletics in March 2023, World Athletics (2023). Both federations reached the same conclusion: transgender female athletes could only compete if they transitioned prior to male puberty at about age 12 and if they maintained testosterone levels <2.5 nmol/L for one year. Many jurisdictions do not allow transition for pre-pubescent males or females at all. Further, those that provide health care for early transitioners, such as in Kaltiala (2023) and Durden (2023), are warning that many pre-pubescent transitioners are showing alarming signs of physical and psychological duress after making that decision. Kaltiala indicated that if they wait until about age 18 post-puberty, 80% who were questioning whether their birth sex is their preferential gender change their minds and remain with their sex of birth, rather than decide too late that they did not really want to transition. As these warnings are heeded, few if any elite transgender female athletes will transition before puberty and thus few if any would be eligible to compete in the Olympics or world championships under current World Athletics and World Aquatics rules.

If a reasonable level of testosterone would be required of all transgender female athletes, regardless of when they transitioned, it would be up to them to try to successfully make the attempt to meet the testosterone limit, rather than be denied that opportunity altogether. In this paper, we are dealing with elite athletes of Olympic caliber, but it is also very important for various jurisdictions to establish fair eligibility requirements for young transgender female athletes at any level who want to compete against those who have been females from birth. It is a matter of fairness for the transgender athletes to be able to compete and for the female athletes born female to be able to compete in a fair environment. Both are important for the integrity of sport in general.

Handelman et al. (2018) noted a study in which the reduction of testosterone for transgender female athletes resulted in a reduction of muscle mass by 9.4% and a reduction of hemoglobin by 14%, both of which would reduce performance. A testosterone limitation can achieve its goal, if the limit is reasonable.

As was mentioned related to intersex female athletes, a limit <2.5 nmol/L was considered too low by Handelman et al. (2018), because some biological female athletes might exceed any limit below 5 nmol/L due to legitimate medical issues, and unfairly be disqualified. They concluded that a fair limit would be <5 nmol/L. It is important to conduct actual tests to see if <5 nmol/L is achievable without requiring a gonadectomy or creating wellness issues.

Sociological affects upon Athletes Seeking Qualification in Sport

In addition to considering the objective technology used to establish rules for allowing intersex female athletes and transgender female athletes to compete, we must also examine the sociological affects upon the athletes who are sensitive individuals also seeking social acceptance.

For example, as Castor Semenya sought to have testosterone limits raised, she found herself having to describe embarrassing personal intersex anatomical features to the media. She said that the medications she was required to take to suppress circulating testosterone made her consistently ill. Since she and other similar athletes were just "born that way" I suggest her sociological status and that of similar athletes would be much improved by taking no action. If some value must be required to satisfy World Athletics and World Aquatics, and since Castor Semenya was able to achieve 10 nmol/L and compete successfully, that would be my suggestion for a workable value for all intersex female athletes, if one must be employed.

Regarding a transgender elite female athlete, she has her sports goals dashed with negative effects on her psychological wellbeing by learning that she must have transitioned prior to male puberty, which few if any have done. Instead, since World Athletics and World Aquatics once chose 5 nmol/L as a testosterone limit for intersex female athletes, using that value for all transgender female athletes, regardless of when they transitioned, would give them all a light at the end of their psychological and physiological tunnel.

Conclusions

We applaud the great world champions who have special physicality. We accept that they were born that way.

Sport strongly restricts intersex female athletes who were simply born that way and ought to have no restrictions like the world record holders. A limit of 10 nmol/L seems the fairest if a limit is needed. Any lower limit would have medical and psychological side effects.

Transgender women purposely changed gender from the sex assigned at birth. Few will be able to transition before age 12 due to needing parental approval and due to legal age restrictions. Following the very substantive paper mentioned earlier, to compete as an equal to female-born athletes, it is reasonable to limit testosterone level to <5 nmol/L for transgender female athletes, regardless of when they transitioned. since transgender athletes are undergoing significant hormone therapy aimed at avoiding side effects. It is important to conduct tests to see if <5 nmol/L is achievable without requiring a gonadectomy or creating wellness issues.

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