A Literature Review of Women in Skiing: Biomechanical, Physiological, and Psychological Gender Differences Acknowledged by Academic Literature

Developed for the Canadian Ski Instructors Alliance

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Introduction

The goal of this literature review is two-fold: first, the CSIA has requested evidence from academic research regarding the potential differences that exist between men and women in the sport of alpine skiing, and second, the identification of what recommendations exist in terms of coaching women in skiing based on the anticipated biomechanical, physiological, and psychological differences. A literature review by Dugan (2005) points out the importance of such work from the perspective of the medical community:

> Although female athletes experience similar injuries to men in comparable sports, there are some types of […] injuries that occur more frequently in women. It is paramount that physicians and other health care clinicians and researchers in the field of sports medicine determine the causative factors in this inequity as we continue to study maximization of sports functioning for our athletes. Gender differences in […] epidemiology, anatomy, neuromuscular control, and training and conditioning must be addressed. (p. 123)

Furthermore, a review by Griffin and colleagues (2000) emphasized the importance of considering male and female differences, particularly in regards to anatomical differences in alignment, muscle development, joint laxity, motion patterns, and even hormones. A one-size-fits-all approach is not appropriate to many aspects of life, and the domain of coaching and training is not exempt from this.

The following literature review has been divided into 4 overarching categories: articles pertaining to biomechanics, physiology, and psychology, and information presented in other programs around the world that are catered to coaching women. It should be noted that this literature review intends to provide support for differences in coaching women, state findings that differentiate ideal coaching processes, and introduce any recommendations that are supported to date.

The criteria for article inclusion in general are listed below. If an article did not meet the required criteria, the article was excluded from this review. It should be noted that, in exceptional cases, some findings are included with cautionary concerns regarding the presented results. For example, if a preliminary study found that women in skiing are more task-oriented than men, but the questionnaire used to determine this was not yet proven valid, but has been proven valid in a later study, the finding would be included with a cautionary statement.

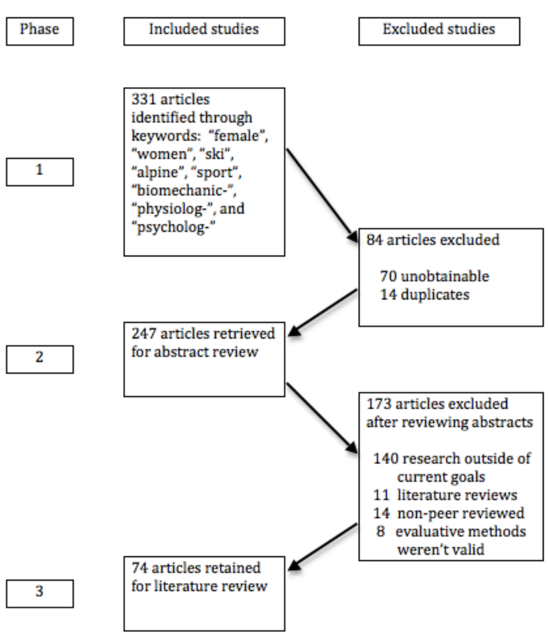
After my initial meeting with some of the CSIA staff, specific areas were targeted for this review. Videos submitted from CSIA training sessions and some anecdotal evidence illustrated differences in techniques and body positions used by men and women who were completing the same tasks. For this reason, extra emphasis was placed on biomechanical differences between men and women to understand why these differences exist, what instructors/coaches should be aware of, and any recommendations to improve performance based on the review’s findings. It should be noted that physiology-related articles were more difficult to come by, as little literature exists at this time in the domain of differences in sport that could be pertinent to skiing. A brief explanation of the methods used for this review will be discussed in the following section.

I would like to thank some of my academic colleagues for reviewing appropriate sections of this review to ensure that the material being provided is valid and reliable. Firstly, Carmelle Mongeon, a physiotherapist from Carleton University, reviewed the biomechanics section. Secondly, Amy Bell, a recent graduate of the Master of Human Kinetics program at the University of Ottawa reviewed the physiology section. Finally, PhD Candidate Erin Kraft, who holds a Master of Education degree, assisted in the review of the psychology section of this review. Finally, I would like to thank my PhD supervisor, Dr. Diane Culver, for her support and guidance in this literature review project.

Methods

Articles were initially searched using Google Scholar and the University of Ottawa's library tools, as well as academic databases that included, but were not limited to, the Journal of Applied Physiology, the Journal of Medicine and Science in Sports and Exercise, the British Medical Journal, the Journal of Psychology of Sport and Exercise, the Journal of Education and Training Studies, the Journal of Sports Medicine, and the Journal of Sport Behavior. This initial search was conducted using the following key words in various combinations: "female", "women", "alpine", "ski", "sport", "physiolog-", "biomechanic-", and "psycholog-". The researcher looked for articles beyond the sport of alpine skiing for two principle reasons: (1) little relevant research currently exists regarding training women in alpine skiing, and (2) if literature in other sporting domains suggests that differences exist between men and women or otherwise have recommendations or perspectives regarding coaching/instructing women, then these could be useful toward the CSIA's goals.

331 articles were deemed relevant to the current investigation, based on article titles found in the initial search process. Of these, 70 were excluded due to accessibility issues. Furthermore, 14 duplicates were removed to yield 247 articles for the next phase of review. The remaining article abstracts were examined to determine relevance toward the current research goals. Based on this phase of analysis, 173 articles have been excluded from this review. Reasons of exclusion included a primary focus on equipment mechanics (physical equipment design, equipment-related injuries, and the use of equipment in races), technology for ski technique analysis, alpine course design specifications, acted as a secondary literature source (i.e. literature review or textbook chapter), was an unpublished university thesis, was removed due to validity/reliability issues, articles that focused on athletes with particular pre-



existing injuries in sports outside of skiing, nutritional supplements as relating to professional sport, and surveys of women's positions in the sporting community (where most women worked), and a review of skiing regulations. These topics were deemed outside of the goals of the current research based on a meeting with CSIA members on May 7th of 2017. Thus, 74 articles were retained for the final phase of review. The image shows the aforementioned process of article elimination and inclusion. It should be noted that a few literature review articles were retained to provide a frame of reference for the current investigations, but were not used as evidence to support the current research goals.

Results

Biomechanics

Thirty-eight articles in this review corresponded only to the category of biomechanics, while eight additional articles yielded information directed toward biomechanics and one or more additional categories. Sub-domains within the area of biomechanical research will include evidence of general physiological differences between males and females, injuries, movement mechanics, differences in training impacts and strategies, and additional recommendations.

Evidence of differences between male and female athletes.

To begin, a number of the biomechanically-focused articles in this review identified differences in female and male athletes. For example, in a study largely focused on the training of the quadriceps, Colliander and Tesch (1990) stated: "concentric peak torque, relative to body weight, was greater in males than in females before and after training" (p. 151). Additionally, Borotikar, Newcomer, Koppes, and McLean (2008) and Liederbach, Kremenic, Orishimo, Pappas, and Hagins (2014) identified that male and female athletes of different sports had different athletic stance jumping strategies that were even further differentiated by fatigue. Similar gender differences in movement were also reflected in the work by Cowley, Ford, Myer, Kernozek, and Hewett (2006) regarding joint angles in various athletic maneuvers. Although these research examples only begin to scratch the surface of the biomechanical differences that exist based on gender, they provide important insight into why athletic programs should consider building training programs that cater to gender differentiations. Furthermore, these fundamental differences considered, it is not surprising that dissimilarities are found in body structure, injury mechanisms, movement impacts, and training effects between males and females. These subdivisions of biomechanical functions are explored in detail below.

Injuries.

One of the most frequently discussed areas of biomechanics regarding gender differences lies in the domain of injuries. Many of the articles found in this review consider injuries relating to various sports, including skiing. Overall, the most commonly reported differences pertained to females incurring more injuries to the knees and lower limbs than males, while males tended to have more injuries in the upper body, including to the face and hands.

In order to begin the illustration of lower limb injuries more clearly, a retrospective study by Stenroos and Handolin (2014) identified that female skiers' incidence of lower leg injury was significantly higher than that of males. Another similar example comes from Baker, Peckham, Pupparo, and Sanborn (1985), who conducted a medical review of meniscal injuries in the United States between the years of 1973 and 1982. They reported that the overall ratio of males to females in the general population regarding meniscal injuries was 3:1, but in the skiing population, females significantly outnumbered the males (Baker et al., 1985). Their results indicated, "female skiers are at equal or greater risk of meniscal injury compared to male skiers" (Baker et al., 1985, p. 3).

Continuing on with lower leg injuries, a study by DeHaven and Lintner (1986) attempted to evaluate female knee injuries as compared to males, particularly considering different sports and age groups. For the purposes of this investigation, only differences between the male and female populations are included in this review. Cases were considered from a Health Centre in New York State between the years of 1975 and 1983. Of the patients documented, only 19.7% were female. Sprains and strains accounted for 28.7% of their injuries, while patellofemoral pain syndrome was the next most popular with 19.6% of diagnoses. Patellofemoral pain syndrome ranked fifth for male injuries, accumulating only 7.4% of diagnoses. The knee accounted for the greatest number of injuries for both genders (DeHaven & Lintner, 1986). One important limitation to this study however was that the article did not specify whether injuries happened during sport participation or due to an outside event. A later study by Myer and colleagues (2010) attempted to investigate precursors to patelofemoral pain, which ultimately suggested that female athletes with increased knee abduction during landing tasks are more likely to develop and increase the incidence of patellofemoral pain. As such, frontal plane loading should be monitored and corrected in similar types of tasks.

To further the above perspectives on knee injuries, Hewett, Myer, and Ford (2006) considered anterior cruciate ligament (ACL) injury mechanisms and risk factors for female athletes. A number of theories have been proposed to explain the significantly greater incidence of ACL injuries in females over males, including intrinsic factors such as anatomical, neuromuscular, biomechanical, and even hormonal differences, as well as extrinsic factors such as visual and physical perturbations and bracing (Hewett et al., 2006). For the purposes of this review, this article will not be discussed at length as it is a literature review, and thus a secondary source. However, it should be noted that Hewett and colleagues' (2006) research found evidence of anthropometric/anatomical differences between males and females, particularly considering tibia length and thigh length, as well as height, static alignment considering shape of pelvis and hips, increased general joint laxity in women, and flexibility, among many other factors. These findings are also supported with a study by Raschner and colleagues (2012), in which they concluded that female ski racers held two times the risk of acquiring ACL injuries when compared with male ski racers. This 10-year retrospective study, involving 195 male and 175 female adolescent ski racers attributed anatomical differences, hormonal influences, and core strength, among some other functional influences, as factors in explaining the large difference in ACL injury frequency between men and women (Raschner et al., 2012). Similar findings were reported by Stevenson, Webster, Johnson, and Beynoon (1998) in their quantitative study of alpine ski injuries for NCAA Division I athletes in the New England area. The results of this study indicated that female alpine racers were 2.3 times more likely than males to have sustained a knee injury and 3.1 times more likely to have incurred an ACL injury (Stevenson et al., 1998). Furthermore, Ruedl and colleagues (2012) considered both female and male recreational alpine skiers in a cohort study to see if leg dominance, along with gender, could be a risk factor for ACL injuries. This study recruited 65 male and 128 female participants who suffered from noncontact ACL ruptures. After considering leg dominance for both groups, the researchers found that female skiers were two-times as likely to suffer from an ACL rupture in their non-dominant leg than males were (Ruedl et al., 2012). Finally, the aforementioned study by Stenroos and Handolin (2014) reported in their two-year retrospective investigation that "females accounted for one third of the study population and had three quarters of all observed ACL injuries" (p. 4).

Another injury-focused study was conducted by Emshoff, Schöning, Röthler, and Waldhart (1997). This investigation analyzed trends in sports-related facial traumas between the years of 1984 and 1993 in Austria. This retrospective analysis indicated that skiing was the most causative factor in sports-related mandibular fractures, representing 55.3% of a 224 participant sample. 70% of the skiers who sustained a mandibular fracture were males, and 30% were females. Once again, this study illustrates a difference in injury occurrence based on gender. This could be due to a number of factors, including athlete build, facial structure, but also psychological factors including risk-taking behaviours. A limitation to this study was that the events that led to the sustainment of this type of injury were not specified and thus some confounding variables were not considered.

Contrary to the above academic evidence, Westin, Alricsson, and Werner (2012) found no significant differences between male and female adolescent skiers in regards to the previously mentioned injury locations. This 5-year cohort study considered 431 skiers (215 male, 216 female) and did, however, note that the only gender difference they found was that males reported more injuries to the hand/finger/thumb than females did (Westin et al., 2012). However, this study was isolated to the high school students at specific Swedish skiing schools and are therefore largely not generalizable.

Movement mechanics.

Beyond injuries, movement mechanics also counted as a popular topic in the biomechanics literature. Borotikar and colleagues (2008) conducted a study focused on the combined effects of decision-making and neuromuscular fatigue on hip, knee, and ankle kinematics. This study included female athletes from basketball, soccer, and volleyball, and analyzed the athletes in a single-leg landing task. One of the most noteworthy findings from this study was that "hip control was substantially altered during fatigue, with subjects tending to land with decreased hip flexion and increased hip internal rotation when in this state" (Borotikar et al., 2008, p. 88). More particularly,

> Neuromuscular fatigue promotes significant decreases in initial contact hip flexion and significant increases in initial contact hip internal rotation, and in peak stance (0-50%) phase knee abduction, knee internal rotation and ankle supination positions during the execution of dynamic single leg landings. (Borotikar et al., 2008, p. 90)

This position is suggested to not only decrease balance, but also increase an athlete's vulnerability to injury. Additionally, hip flexion, internal rotation, and knee abduction positions were reported as being even more pronounced when landings were unanticipated. Borotikar and colleagues (2008) suggest that hip and gluteal fatigue play an enormous role in the loss balance and movement control, and should thus be focused on in the training of female athletes to decrease the potential of injury during fatigued states. These training alterations would likely change the body center of mass on landing and could lead to a lower likelihood of the lower limb collapse that could otherwise occur (Borotikar et al., 2008). This is particularly important in a high-risk, dynamic sport like skiing. Federolf and colleagues (2008) support the importance of body posture and control in skiing as ski angles can significantly impact gliding times. Building on this notion of body posture and control, Marras, Jorgensen, Granata, and Wiand (2001) did a gender-specific study in which they compared the trunk geometry between ten males and twenty females. This study revealed significant differences in males and females regarding the physiological cross-sectional area of the erector spine, internal and external obliques, psoas major and quadratus lumborum (Marras et al., 2001). Additionally, females demonstrated more significant differences in right and left sided-muscles when compared to the differences seen in males (Marras et al., 2001). It should be noted that, the sample size for female participants is good for a study of this nature, but the sample size for male participants is only adequate; ideally, the sample size for this study should aim for around twenty participants in both groups. However, once again there is evidence of differences between males and females, thus suggesting that gender factors and anatomy should be taken into account when considering biomechanical functions.

Salci, Kentel, Heycan, Akin, and Korkusuz (2004) compared the landing maneuvers used by eight male and eight female university volleyball players. Through the use of a number of reliable motion-analysis systems and recordings, differences were identified between the male and female players. For one, female athletes in the study displayed a greater degree of knee flexion than males did in the same landing task, from the same heights and directions. Females also displayed reduced hip flexion during landings (Salci et al., 2004). Particularly, Salci and colleagues noted (2004):

> If reduced hip flexion postures are used for landing, that is common to volleyball spikes, then the quadriceps' high compensatory knee extensor torques, acting in combination with large ground reaction forces, may excessively accelerate the tibia anteriorly beneath the femur; hence, ACL injury may be incurred. (p. 625)

Although these findings are specific to volleyball movements, this study illustrates another difference in movement mechanics between males and females in other athletic domains.

Keeping in line with gender differences in single leg landings, Ford and colleagues (2006) considered eleven female and eleven male athletes from soccer and basketball to assess coronal plan excursion and direction of motion during single-leg landing tasks. The athletes in this study were randomly asked to jump off of a block either medially or laterally, to land on the same leg and balance their landing leg for approximately two seconds. The most significant findings in this study were noted in regards to hip, knee, and ankle coronal plane excursions; more particularly, these excursions were greater for females in the medial landings, while only the hip and knee excursions were greater in the lateral landings (Ford et al., 2006).

A previously mentioned study by Cowley and colleagues (2006) compared lower extremity biomechanics in female basketball and soccer players during jumping and cutting tasks. Primarily, they note that a number of previous studies explain that females exhibit greater knee valgus angles than males in both landing and cutting maneuvers. They elaborate that the mechanisms for injury in each sport may differ despite similarities in injury risk factors. However, significant differences were noted in ground reaction forces and stances in both analyzed movements. As a result, sport-specific neuromuscular training is recommended (Cowley et al., 2006). Similar findings were noted by Orishimo, Liederbach, Kremenic, Hagins, and Pappas (2014) regarding females exhibiting a greater knee valgus in both team sport athletes and dancers.

Further support for gender differences in plane biomechanics was presented by Kernozek, Torry, Van Hoof, Cowley, and Tanner (2005). Focusing on lower-extremity joint kinematics and kinetics, the researchers considered the frontal and saggital planes during drop landings with 15 male and 15 female recreation athletes (Kernozek et al., 2005). Their results suggested “that gender differences in knee joint biomechanics exist and are more evident in the frontal plane than in the saggital plane during drop landings” (Kernozek et al., 2005, p. 1006). For one, females in the study exhibited greater peak knee valgus angles in the landing phase. The authors suggested these findings might actually be due to anatomical differences that exist between males and females (Kernozek et al., 2005). Kernozek and colleagues (2005) clarified that “females tend to possess a larger Q-angle (relationship of femoral axis relative to the tibial axis measured at the knee in the frontal plane), which is often associated with an increased knee valgus position” (p. 1007). Finally, Kernozek and colleagues (2005) also noted that after accounting for the body mass of each individual athlete, females generated a smaller internal knee varus moment at the moment of peak knee angulation as compared to males. The correlational nature of this study does not allow for any causational statements to be made, but it does provide further evidence of biomechanical differences between males and females.

Haymes and Dickinson (1980) focused specifically on elite skiers in three different disciplines (Alpine, Cross-country, and Nordic skiing). They explained:

> Male skiers produced more power adjusted for weight or lean body weight than female skiers in the same discipline. Examination of the isokinetic strength data for the alpine skiers at two different rates of contraction, 30 degrees and 180 degrees/second, suggests that the female skiers could not produce as much torque per kilogram of lean body weight as the higher rate of contraction compared to the males. (Haymes & Dickinson, 1980, p. 157)

It should be noted that this research was conducted nearly forty years ago and should be approached with caution, despite the use of valid and reliable measures at the time. It does however raise a suspicion regarding male and female training impacts. Traditionally, male and female athletes have been approached using the same training techniques, so it raises questions as to whether a female-specific training regime would increase performance in these tests, as well as in performance in their respective sports in general.

Additionally, McLean, Lipfert, and van den Bogert (2004) explored lower limb kinematics while comparing athletes from three different sports, as well as gender differences within those athletic domains. Similarly to a number of the studies above, females landed in a more extended position with smaller flexion values in shuttle run movements, when compared to males. However, this difference did not occur across all movements tested in the study; gender differences did, however, exist in all three conditions (including side-stepping and jumping conditions) regarding peak knee valgus, hip flexion-extension, knee flexion-extension, and knee varus-valgus. The researchers suggested:

> Gender differences in hip and knee sagittal plane motions may be dependent both on the population and task(s) being tested. This likely also explains why some studies have found females actually elicit increased knee flexion compared to males during similar movements. (McLean et al., 2004, p. 1014)

The significance of these findings in relation to the current research goals are important for consideration as alpine skiing involves a number of cutting, jumping, and landing maneuvers that are considered in the aforementioned studies. Although not all of the above studies' findings are generalizable to skiing, they are still nonetheless important to consider when developing female-specific programs as differences in one sport could translate to similar differences in another. Regardless, the above findings are important to contemplate when considering the dynamic and dangerous nature of skiing.

A study by Nakagawa, Moriya, Maciel, and Serrão (2012) attempted to compare the frontal plane biomechanics of males and females, while considering samples of people with and without patellofemoral pain. More particularly, it aimed to compare the ipsilateral trunk lean, hip adduction, knee abduction excursion, contralateral pelvis drop, and gluteus medius activity at various degrees of knee flexion during the upward and downward phases of stepping maneuvers (Nakagawa et al., 2012). Eighty recreational athletes were selected for this cross-sectional study; twenty belonged to the female group with patellofemoral pain syndrome (PFPS), twenty to the female group without PFPS, twenty to the male group with PFPS, and twenty to the male group without PFPS. The young adult athletes engaged in aerobic exercise or sport at least three times per week and had to meet a series of other criteria for study participation. Overall, as with previous studies cited by the researchers:

> Females presented less capacity to generate isometric hip abductor torque, accompanied by greater hip adduction and knee abduction at all the angles evaluated in the stepping maneuver. [Gluteus medius] activation was increased during almost the whole maneuver, except for 15 degrees and 30 degrees of knee flexion in the upward phase. Increased contralateral pelvic drop and ipsilateral trunk lean only occurred later during the stepping maneuver, from 60 degree of knee flexion up to the end of the maneuver. (Nakagawa et al., 2012, p. 1752)

The researchers attributed differences in hip movement in the frontal plane to greater gluteus medius activation to compensate for their reduced muscle strength in the hip area (Nakagawa et al., 2012). Nakagawa and colleagues (2012) also suggested that increased ipsilateral trunk lean in female participants acted as a compensatory mechanism for reduced strength found in hip abduction, which also increased knee abduction load. For females, they recommended hip abductor strengthening and motor control training to help with these functional movements in order to adjust for the increased risk of injury that females hold based on their biomechanical functions and anatomical structure (Nakagawa et al., 2012). In another study focusing on female recreational runners, similar findings were revealed regarding increased female hip adduction and peak knee internal rotation, which correlates with the development of illiotibial band syndrome (ITBS) and furthers its development (Noehren, Davis, & Hamill, 2007). As a result, Noehren and colleagues (2007) suggest strength and neuromuscular control training of the hip for female runners, particularly those with ITBS.

Differences in movement mechanics are not only visible at a complex level, as seen above, but also during simpler movements like walking. A study by Kerrigan, Todd, and Croce (1998) considered gender difference in joint biomechanics while 49 adult female and 50 adult male participants walked. Among the significant differences noted, females showed greater hip flexion and less knee extension before making initial contact with the foot. Furthermore, females exhibited a significantly greater knee flexion moment in the pre-swing and greater peak mechanical joint power absorption in the same phase (Kerrigan et al., 1998).

Differences in training impacts and strategies.

Another important aspect considered by the literature reviewed was the difference of training strategies and impacts in males and females. Colliander and Tesch (1990), for example, considered the effects of a short-term resistance-training program targeting eccentric and concentric maximum voluntary quadriceps' muscle actions. It was noted that concentric and eccentric peak torque increased in both training groups, regardless of angular velocity. Males experienced greater absolute increases in unilateral concentric, bilateral concentric, and peak torque across speeds and muscle action modes than females. However, "unilateral eccentric/concentric peak torque ratio increased more in females than in males with increasing angular velocity" (Colliander & Tesch, 1990, p. 153). This study was not conclusive in its evidence, but did state that only males showed a change in the velocity-torque relationship, provoked by a greater relative increase in the high-force and slow-speed region.

A later study by Herman and colleagues (2008) focused on strength training of the lower extremity muscles for 9 weeks in female athletes and found "a significant increase in selected muscle strengths but [the training results] did not show any significant strength effects on any of the selected lower extremity kinematics and kinetics" (p. 740). Thus, strength training alone is not enough to alter lower extremity biomechanics, but may be useful in conjunction with other methods to improve mechanics and reduce the risk of sustaining lower extremity injuries, such as non-contact ACL injuries (Herman et al., 2008). In a study a year later, Herman and colleagues (2009) considered video-feedback instruction as a method for improving the strength training of lower extremity biomechanics. This study furthered the previous study by concluding that "the significant interaction effects demonstrated in our results indicate that strength training may provide an increased capacity for the alteration of knee and hip kinematics and kinetics when used in conjunction with video-assisted feedback" (Herman et al., 2009, p. 1305). This study also included verbal corrective instruction along with the video-feedback and showed positive and significant changes across all female participants (Herman et al., 2009), thus suggesting that the role of the coach in providing proper mechanical feedback, both verbally and through videos, during training is crucial to the performance of landing, stopping, and jumping tasks. These findings were further supported in an article by Parsons and Alexander (2012) that analyzed how modifying spike jump landing biomechanics in female adolescent volleyball players could be done through the use of video and verbal feedback. They concluded that "augmented feedback appeared to produce a positive change in landing biomechanics in adolescent female volleyball athletes performing a sports-specific skill" (Parsons & Alexander, 2012, p. 1076).

Hewett, Lindenfeld, Riccobene, and Noyes (1999) considered neuromuscular training as a method for decreasing the incidence rate of knee injuries in female athletes. Indeed, when comparing four hundred and sixty-three female athletes who were not trained with the program had a significantly higher rate (3.6 times higher) of knee injury than the three hundred and sixty-six female athletes who were trained with the program. This 6-week neuromuscular program was conducted in the athletes' pre-season, incorporating flexibility, plyometrics, and weight training. This program attempted to decrease landing forces, as well as adduction and abduction moments, among some physiological benefits as well, which will be discussed in the physiology section below.

Along with the aforementioned training strategies, Pfile and colleagues (2013) introduced two different training interventions to female athletes during their respective sport seasons. The first of these training programs focused on core stability, while the second focused on plyometric training. When pre- and post-tests were considered, both programs resulted in positive biomechanical changes; the core stability group adopted decreased knee-flexion and knee internal-rotation, as well as hip-flexion and hip internal rotation moments, while the plyometric group saw decreases in knee-flexion, internal-rotation angles, and knee-flexion/abduction moments (Pfile et al., 2013). These findings not only suggest that similar training interventions can lead to strong knee, hip, and trunk kinetics and kinematics, but also reduce lower-extremity injury potential (Pfile et al., 2013).

Similarly, Pollard, Sigward, Ota, Landford, and Powers (2006) introduced an in-season training program designed to help prevent hip and knee injuries for female soccer players. This longitudinal pre-post test intervention with 18 adolescent female participants illustrated that females who completed the program presented significantly less hip internal rotation and significantly greater hip abduction. This change in lower extremity motions was also suggested as having a role in effectively lowering female athletes' predisposition toward ACL injury (Pollard et al., 2006). These findings, although positive, should be approached with caution due to the small sample size of the study and the lack of multi-variable analysis to consider possible confounding variables.

An interesting pre-test/post-test study by Myer, Ford, Brent, and Hewett (2006) compared the effects of dynamic neuromuscular stabilization and balance training and plyometric training in female athletes regarding landing force. Nineteen female high school volleyball athletes were chosen for this study, twelve of which listed a variety of secondary sports including basketball, soccer, softball, and swimming (Myer, Ford, Brent, et al., 2006). These programs were admitted during the off-seasons for these athletes and were admitted by certified professionals from the National Strength and Conditioning Association, graduate students, and undergraduate students, as approved by the Cincinnati Children's Hospital Medical Center Institutional Review Board. The training programs were slightly modified from a training protocol that has been shown to increase measures of performance and decrease biomechanical measures related to ACL injuries (Myer, Ford, Brent, et al., 2006). Pre-testing occurred before the programs started, then both programs were admitted three times a week, with two training sessions a day, for eight weeks, after which post-testing occurred. Images of examples of the training programs have been provided in Appendix. The results of this study revealed that both plyometric and neuromuscular balance training were effective at improving lower extremity neuromuscular control and power, as well as decreasing leg dominance in the female athletes. The researchers did note that the balance training might be more beneficial for improving single leg force attenuation strategies, while balance training and plyometrics could further maximize pre-season training efforts for female athletes in general. The overall improvements in performance, power, body sway, and dynamic strength were significant in both groups (Myer, Ford, Brent, et al., 2006). In the same year, Myer, Ford, McLean, and Hewett (2006) compared similar training methods for eighteen female athletes while targeting lower extremity biomechanics while comparing jumping and cutting exercises, which yielded similar results. More particularly, the researchers noted that both balance and plyometric training can reduce measures of lower extremity valgus, with plyometric training apparently targeting sagittal plane kinematics in vertical drop/jump and balance improving sagittal plane kinematics in single leg drop landings (Myer, Ford, McLean, et al., 2006). Similar findings regarding neuromuscular training improvements in lower-extremity biomechanics were noted by Myer, Ford, Palumbo, and Hewett (2005) over a six-week training program with forty-one female basketball, volleyball, and soccer players.

A study by Seynnes and colleagues (2011) aimed to test whether a supervised alpine skiing program would affect the mechanical properties of tendons in older females and males. Twenty-one masters skiers (a median age of sixty-seven) participated in a twelve-week guided skiing program, which involved two or three 3.5 hour training sessions per week. Prior to and following the program, participants were tested on maximal voluntary contraction of the knee extensor muscles, tendon size, and mechanical properties along with body mass, and blood sampling and serum analysis to consider factors like growth hormones and insulin-like growth factor-binding proteins. These factors were also evaluated against a control group of 18 comparably aged athletes. The results of this study pointed to older females "displaying a blunted increase in tendon stiffness" (p. 43) when compared with older males in general (Seynnes et al., 2011). More particularly, Seynnes and colleagues (2011) reported that the effects of training on the mechanical properties of tendons were gender specific. Due to the longitudinal and pre-test/post-test nature of this study and the use of valid and reliable measurements, the results of this study are significant to the current research goals as they demonstrate a difference in training impacts on men and women, even at older ages. Seynnes and colleagues (2011) do request further validation before the following statement is held with validity, but they do suggest that this pattern of training exposure and tendon stiffness could indicate that women are at a higher risk of sustaining soft tissue injuries, even after menopause, despite a decrease in estrogen levels.

Additional recommendations.

According to Hass and colleagues (2005), not only is it important to consider the differences in body mechanics between males and females, but also within females based on development changes through puberty. Their study considered the knee biomechanics of sixteen recreationally active girls between the ages of eight and twelve, and sixteen recreationally active women between the ages of eighteen and twenty-five. Variables of interest included: (a) the angle of knee flexion at the instant of jump touchdown, (b) the landing phase duration based on the time of initial ground-foot contact to maximal knee flexion, (c) knee abduction range of motion and knee flexion during the landing phase, (d) the peak magnitude of the posterior ground reaction force (GRF), (e) the timing and magnitude of the peak vertical GRF, (f) peak knee medial-lateral and anterior posterior joint forces, and (g) the peak knee abduction-adduction and extensor moments (Hass et al., 2005). As hypothesized, prepubescent athletes landed with a more flexed knee position, providing partial protection to the knee's internal structures. Previous literature has suggested this difference could be due to increased loading of various muscle groups, as well as differing activations based on muscle and bone size (Hass et al., 2005). It was further recommended that training aimed at improving landing performance has been previously shown as a way of increasing knee flexion angles, as well as reducing ground reaction forces in both pre- and post-pubescent females, thus reducing the risk of injuries (Hass et al., 2005). Additionally, Hass and colleagues (2005) recommend incorporating motor control training strategies with female athletes to improve landing mechanics.

An additional recommendation supported by the literature came from a study by Milner, Fairbrother, Srivatsan, and Zhang (2012). This study aimed to test if simple verbal instructions could immediately alter the knee biomechanics of female athletes during landing movements. Twelve females adult athletes between the ages of eighteen and thirty-five participated in the study and were verbally instructed to "step on the force plates with one leg on each plate, squat as low as you require, jump up as high as possible, and land on the force plates with one leg on each plate" (Milner et al., 2012, p. 400). This served as the control condition, which always occurred first. Then, three different simple instructions were provided one at a time, in a methodologically determined random order for each of the twelve participants, with a two-minute break between each condition. The three simple instructions were to land *with knees over your toes*, *with equal weight distribution on both your feet*, and *as softly as possible*. As predicted, each of the three simple verbal instructions successfully altered the individual's knee biomechanics. The 'soft' condition resulted in athletes landing with an increased knee flexion angle and a decreased peak vertical ground reaction force, when compared with the control condition. The 'knees over toes' condition resulted in an increased peak knee flexion angle. Finally, the 'equal weight distribution' condition resulted in athletes demonstrating greater symmetry of the vertical ground reaction force during landings (Milner et al., 2012). All in all, the findings of this study suggest that verbal instructions could be useful in reducing knee injury risk in female athletes (Milner et al., 2012). Beyond this, simple verbal instructions during training and coaching situations may help increase athlete responsiveness and understanding of movements. This has been a common theme across a variety of sporting programs for instructional training, including Hockey Canada's instruction-specific technical programs. Principally, the idea that coaching athletes to do the proper skating or shooting technique should not be done through the repeated use of complex instructions, nor through providing multiple instructions at once, but rather focusing on a specific aspect of the movement and reiterating that point before moving onto the next instruction (Gillam, 2017).

Yet another recommendation regarding the improvement of biomechanics in movement was provided by Ford and colleagues (2005). This study examined how the use of an overhead goal could change vertical jump performance in NCAA Division I male and female soccer players. This randomized, repeated-measures experimental design was implemented right before the start of the athletes' respective seasons. Although both male and female athletes improved their jump height with an overhead goal, the jump strategy was different. More particularly, "gender differences were found during the plyometric movement both with and without the overhead goal" (Ford et al., 2005, p. 397). With further explanation, Ford and colleagues (2005) noted that men employed eighteen percent more hip extensor activation, particularly in their use of gluteus maximus and hamstring muscles, when compared with women. The researchers suggested that these differences could not only explain some of the height differences gained, but also illustrate how men and women might respond differently to training techniques and approaches to athletic tasks (Ford et al., 2005). Furthermore, the use of extrinsic motivators such as overhead goals or other types of external targets could indeed improve training strategies, performance, and injury prevention efforts in female athletes (Ford et al., 2005).

Physiology

Eight articles in this review corresponded only to the category of physiology, while five additional articles yielded information directed toward physiology and one or more additional categories. As described by Tesch (1995) "Alpine skiing is characterized by substantial demands on both aerobic and anaerobic metabolism" (p. 313), thus these two physiological areas are most targeted in the current review. Sub-domains within the area of physiological research will include evidence of general physiological differences between males and females, and differences in training impacts and strategies.

Evidence of differences between male and female athletes.

Similarly to the category of biomechanics, articles within the physiology category expressed differences between male and female athletes. To begin, Baxter-Jones, Goldstein, and Helms (1993) identified a distinct pattern between males and females regarding maximal oxygen uptake capacity ($VO_{2\ max}$) in the pubertal stage; untrained males showed a significant increase in their aerobic power toward the end of puberty, which was not found in untrained females. Additionally, they attributed age, physical growth, and maturation as confounding variables in the development of increased aerobic power with training. This effect was more noticeable in more aerobic sports, such as swimming (Baxter-Jones et al., 1993).

While further considering physiology through gender comparisons, Maldonado-Martin, Mujika, and Padilla (2004) investigated gender-specific physiological traits of highly trained middle and long-distance runners. Although the study had a relatively small sample size (seventeen males, eleven females), the results indicated that male runners had a significantly higher aerobic profile when considering $VO_{2\ max}$, blood lactate concentration, lactate threshold, and maximal aerobic velocity in comparison to females of a similar performance level. Additionally, Maldonado-Martin and colleagues (2004) reported that females had a significantly higher percentage of $VO_{2\ max}$ values at the blood lactate concentration, lactate threshold, and submaximal velocities than the male subjects.

As reported in a literature review by Ferguson (2010):

> Alpine skiing is characterized by repeated phases of high-force isometric and eccentric contractions in which all fibre types are likely to be active. The [ischemic] nature of the contractions, brought about by high levels of intramuscular pressure and reduction in blood flow, will inevitably result in an accumulation of metabolic byproducts that will impact on the force-generating properties of muscle [through] various central and peripheral mechanisms. Peripheral fatigue will result through the inhibition of the contractile process. At the same time, central fatigue will result in the stimulation of afferent receptors within the muscle, which will inhibit voluntary activation of the muscle and cause a reduction in force output, as well as impacting on the tightly regulated motor control patterns. Through training, it is possible that elite skiers have a highly adapted peripheral vasculature that allows an enhanced washout of metabolic byproducts and thus reduces the negative influence on muscle activity. (p. 408)

This quote illustrates the importance of a skier's physiology working to the athlete's advantage. If differences exist based on gender in this category, than it would be assumed that training requirements should also be different. As the literature will show, gender differences do exist in physiology, particularly regarding the impact of training strategies, which is further explored in detail below.

Additional evidence of the existence of gender differences on a physiological level was found by Rundell and Bacharach (1995) regarding characteristics of top United States, nationally ranked, biathletes and their respective performance predictors. Although upper and lower body aerobic and anaerobic power were both described as requirements for success, VO_{2peak} and double-pole power were only significant predictors for success for female athletes and not for male athletes. This laboratory-based study provides correlational results only and targets a very specific and small population based on the sample. However, it does further the importance of considering male and female athletes separately, as they will experience the effects of training differently, not only because of their sport, but also due to their gender.

Furthermore, Tanaka and Seals (1997) provided similar insight on physiological functional capacity by looking at both female and male adult swimmers, while also considering age. Regarding endurance swimming at the highest level of competition across several age groups (early adult to masters athletes), performance decreased with age in both men an women, although the biggest decline in performance occurred in shorter duration events. Additionally, the declines in both of these types of performances were greater in magnitude for women than men. It was also noted that the energy expenditure cost for men in a freestyle event was higher than that of women, which the authors attributed to women's general smaller body size, body density, and greater body fat percentages (Tanaka & Seals, 1997). This difference in body size, body fat percentages, aerobic power, and muscle strength based on genders was also acknowledged in an article by Neumayr and colleagues (2003), which considered 28 male and 20 female elite Austrian skiers from the 1997-2000 World Cup seasons.

An article by Haymes and Dickinson (1980) expands on this aforementioned notion. When considering elite male and female skiers in Alpine, Nordic, and Cross-country domains, significant differences were found between males and females with similar training regimes. The article concluded that "maximal oxygen uptakes of the female skiers were considerably lower than those of males skiers" (Haymes & Dickinson, 1980, p. 156). When considering alpine skiers specifically, female alpine skiers held a VO_{2max} that was 23% lower than male skiers of the same category, when divided by weight. One of the contributing variables Haymes and Dickinson (1980) acknowledged was body fat. They explained that fat uses little oxygen, therefore the more lean body weight the athlete has, the higher the potential for a better VO_{2max} (Haymes & Dickinson, 1980). This biological and physiological difference alone suggests that training strategies and impacts will differ based on gender. This is further investigated in the section below.

Differences in training impacts and strategies.

An interesting study by Breil, Weber, Koller, Hoppeler, and Vogt (2010) introduced an eleven-day *shock* microcyle off-season interval-training program with elite junior skiers. The main finding presented was an increase in VO_{2max}, peak power output (PPO) and power output at the second ventilatory threshold (VT_2), as compared to only minor changes in a more traditionally mixed training regiment. Males in the study showed a significantly greater improvement in the total number of jumps they were able to perform in a ninety second high-box test (mean increase of 4.9%) compared to females (mean decrease of 1.6%).

As previously discussed, Hewett, Lindenfeld, Riccobene, and Noyes (1999) considered neuromuscular training as a method for decreasing the incidence rate of knee injuries in female athletes. The six-week neuromuscular program showed some physiological benefits, including decreased estrogen levels and increased hamstring-to-quadriceps ratios, both of which have been associated with decreased injury risk in previous literature (Hewett et al., 1999). Similarly, Raschner and colleagues (2012), as discussed in the biomechanics section, considered gender and physical fitness as risk factors for ACL injuries. This study suggested that core strength and core training could act as a preventative measure for ACL injuries in young ski racers, particularly female racers (Raschner et al., 2012).

White and Johnson (1991) directed a physiological comparison of male and female international, national, and regional Alpine skiers through a variety of fitness tests. Thirty-one males and thirty females participated in the five-part test that suggested anaerobic power tests, such as the Wingate, are most predictive of Alpine skiing ability, and thus anaerobic power was recommended as a target for training for both men and women. One of the main factors contributing to power output, as identified by the researchers, was larger percentages of fat-free mass. Although the entire male sample in the study had a somewhat lower than previously reported mean fat percentage, they suggested that the difference in fat-free mass between men and women could indeed provide reasons for explaining the differences in performance at each of the three competition levels. As such, it would appear that anaerobic training should be a focal point for both genders, but even more so for women, in order to reach higher levels of competition, particularly as anaerobic performance was significantly different between international and national/recreational levels in eight of the nine evaluative criteria (White & Johnson, 1991).

Even within the female sport population, differences have been reported in athletes based on ethnicity. Rawlins and colleagues (2010) conducted a study to see if black female athletes expressed more electric repolarization and left ventricular hypertrophy than white female athletes, as was previously seen with male athletes of the same ethnicities. Indeed, when nationally ranked athletes from various sports were considered, systematic physical exercise in black female athletes is more greatly associated with more optimal left ventricular hypertrophy and a higher prevalence of repolarization changes than what was seen with equally trained white female athletes. The sample size was large enough to warrant the significance of these findings, but further investigation was suggested as the targeted sample for this study is not generalizable to the wider athletic population (Rawlins et al., 2010).

Psychology

Thirty articles in the review corresponded only to the category of psychology, while four additional articles yielded information directed toward psychology and one or more additional categories. Sub-domains within the area of psychological research will include evidence of general psychological differences between males and females, individual orientations in sport, reasons for participation, social factors, and additional recommendations pulled from academic literature.

Evidence of differences between male and female athletes.

As with the categories of biomechanics and physiology, gender differences in sport do exist on the psychological plane. For example, an interesting study by Coulomb-Cabagno and Rascle (2006) looked at observed aggression as a function of sport type, competitive level, and gender. It considered ninety male and ninety female games in two popular French sports, divided over three levels of competition. Each team considered in this study was observed in one home and one away game, both games of which were filmed. The analysis of the videos was conducted via the guidance of respective sport experts and the two researchers. Overall, the results showed that male athletes displayed more hostile and instrumental aggressive behaviours than female athletes did, in line with a number of previously documented academic findings (Coulomb-Cabagno & Rascle, 2006). These findings support the notion that gender differences exist in terms of sport aggression.

Not only are psychological differences between genders present in the area of sport aggression, but also in risk taking behaviour. Ruedl and colleagues (2010) conducted a study in Austria during the 2008-2009 ski season. Speed measurements of skiers and snowboarders were taken from five hundred and twenty-seven skiers over the course of six non-sequential days, between the hours of 10am and 4pm. Upon the completion of their run, the skiers and snowboarders participated in a verbal questionnaire in order to categorize the athletes into one of two categories: risk-takers and cautious skiers/snowboarders. Although there were more males in both the risk-taking skier and cautious skier/snowboarder groups, males were reported as more likely to take risks on the slopes. However, these results come with some important limitations, including the question used to assess risk-taking behaviour, as it was not formally validated prior to its use in this study (Ruedl et al., 2010). This considered, the randomized nature of the study and the precautions taken to account for over- and under-reporting of socially desired behaviour together provide significant merit and validation to the study regardless.

Building on these differences, female and male athletes also cope and respond to stressors differently. Nicholls, Polman, Levy, Taylor, and Cobley (2007) recruited four hundred and fifty-five male and two hundred and ninety-four female undergraduate athletes to participate in an open-ended questionnaire study. This investigation aimed to assess stressors, coping, and coping effectiveness as a function of gender, type of sport, and skill. The results of this study indicated that females regularly used planning as a coping strategy when compared to males, who often used blocking (Nicholls et al., 2007). Stressors reported by females included communication and teammate-related stressors when compared to males who pointed to injuries and errors, more often (Nicholls et al., 2007). Finally, Nicholls and colleagues (2007) reported that females' coping strategies included problem-focused strategies such as planning, communication, and technique-oriented coping. As such, the results indicated that gender contributes to the style of coping strategies employed, and thus coaches should be aware of these approaches when their athletes are faced with stressful situations, in order to optimize communication, approach, and recovery.

Another study by Bredemeier (1994) considered differences in children's moral reasoning and action/behaviour tendencies based on gender. In sport and daily life, males were reported as having a higher frequency of aggressive behaviours and a lower frequency of submissive behaviours, as compared with females. It should be noted that males and females did not differ significantly in moral reasoning in either sport or life. As such, we see evidence of additional behavioural differences between males and females. These and other subdivisions of psychological processes, orientations, and functions are explored in detail below.

Individual orientations and reasons for participation.

One of the most frequently seen differences in this literature analysis was related to reasons for sport participation. A study by Daniels and Leaper (2006) in particular investigated the correlations that existed between adolescent boys' and girls' sport participation, peer acceptance, and self-esteem. This study had an enormous sample size and operated on a longitudinal basis. Not surprisingly, peer acceptance strongly mediated the relationship between global self-esteem and sport participation. Thus, the more accepted an athlete felt in his or her sport, the higher levels of self-esteem he or she reported having. Differences did exist between boys and girls, perhaps most notably in regards to global self-esteem at both the initial intake time and at the time of the study's completion. Furthermore, Daniels and Leaper (2006) noted "physically active girls accepted by their peers are likely to experience increased feelings of global self-esteem" (p. 879). The accumulation of these findings suggests that the more acceptance a female experiences in her sporting environment, the more likely she is to have higher self-esteem, and the more likely she is to continue participating in that sport. This is further supported with an earlier study by Brown, Frankel, and Fennell, in 1989, who claimed "it is not surprising that those who continue their involvement in sport are those who received positive feedback concerning their participation" (p. 407).

Another aspect of sport participation was considered in a study by Guillet, Sarrazin, and Fontayne (2000). The researchers in this study examined sport participation from the perspective of gender roles in a French handball league for athletes between the ages of thirteen and fifteen. Three hundred and thirty six female handball players participated in this questionnaire survey over three years. It was noted by the authors that handball, in the local area, had been traditionally categorized as a masculine sport, and this was taken into consideration when stating one of the most noticeable findings of the study, which suggested that many female participants quit based on social factors. The researchers suggested "the involvement of girls in sport will remain problematic as long as some activities are connoted as being stereotypically masculine, particularly for girls whom conformity with stereotypic images of femininity is all-important" (Guillet et al., 2000, p. 420-421).

Buildling on this alternate perspective of sport participation, Williams and Lattey (1994) considered constraints for Canadian women regarding their non-participation in skiing. The data reported came from a larger telephone survey conducted in 1990 that was directed toward non-skiers. In order to be eligible to participate in the study, non-skiers had to be persons who had never skied before, or who had not skied in the past two years, among other important criteria. Six hundred and ninety-five of the respondents were female and therefore included in this investigation. Notably, socialization was a huge factor for skiing participation; women were more likely to ski if family, friends, or significant others were also involved in the sport (Williams & Lattey, 1994). This aspect of socialization will be further discussed in the next subsection. Additionally, Williams and Lattey (1994) noted that perceptions of lower personal athletic capabilities and frequency of engagement in physical activity (including perceived experience required and minimal participation in other physical activities), along with safety issues were expressed as common constraints for female non-skiers as well. Furthermore, location was an issue for participation for those who lived what they considered to be “too far” from a ski hill, as well as some additional socioeconomic constraints (Williams & Lattey, 1994). These findings appear to be of particular importance to the current research goals as they indicate some of the more highlighted barriers to participation that women experience in regards to skiing.

Another couple of frequently discussed aspects of psychology in sport participation were athlete orientation and performance anxiety. Primarily, female and male elite athletes are reported to have similar perceptions on motivational climate and achievement goal orientations (Abrahamsen, Roberts, & Pensgaard, 2008). However, it was noted that elite female athletes experienced more performance anxiety than elite male athletes did (Abrahamsen et al., 2008). After further analysis, Abrahamsen and colleagues (2008) identified that, “the motivational climate, even though similarly perceived by the athletes, had a different role to play in prediction of performance anxiety with the female and male athletes” (p. 459). Additionally, performance climate actually predicted more disruptions in concentration with female athletes, thus suggesting that, although motivational climate is important for both genders, it may be even more important to female athletes (Abrahamsen, Roberts, & Pensgaard, 2008). When the appropriate motivational performance climate is not present, the female athlete is more likely to experience performance worries, somatic anxiety, and concentration disruptions (Abrahamsen, Roberts, & Pensgaard, 2008).

A study by Martin and Mack (1996) considered the relationship between physical self-presentation, particularly concerning social physique anxiety, physical self-presentation confidence, and sport competition trait anxiety. Ninety-three female and fifty-three male kinesiology students from two universities participated in this questionnaire-based study. According to Martin and Mack (1996), no significant gender difference existed regarding trait anxiety or measures of physical self-presentation confidence. However, the researchers did note that females reported significantly greater social physique anxiety than males did, and women who were most anxious about the potential of having their bodies evaluated by others were also those who reported being most anxious about their sport competition (Martin & Mack, 1996). Based on the results of this study, it would be wise to consider coaching female athletes differently because the results suggest that women are more concerned with their physical appearance during sport performance, which in turn can increase performance anxiety. In line with physical appearance and gender stereotypes, Richman and Shaffer (2000) attempted to address the links between teenaged female athletes’ sport participation and their college self-esteem, through the potential influences of social, cognitive, physical, and emotional perceptions of the self. Based on the results of their two hundred and twenty participant study, Richman and Shaffer (2000) reported, “indeed, greater participation in sports did seem to foster the development of masculine attributes among the women in our sample, and masculinity mediated the relationship between earlier sport participation and later self-esteem” (p. 197). It does seem that, in terms of sports that are regarded as “more feminine”, extra attention may be needed from coaches to try and mitigate these stereotypes, particularly as it seems that more “feminine” athletes show more concern toward their bodies and their appearance during sport participation for the belief that they must look a certain way.

Daniels, Sincharoen, and Campbell (2005) considered sport orientation as a mediator in the relationship between sport participation and adolescent athletic identity.

It was found that males possessed a more goal-oriented attitude regarding sport participation and athletic identity, while females were more win-oriented. A win-orientation reflects a desire to win a game/match/event and avoid losing, thus the evaluation of success is dependent on the athlete's performance compared to the performance of others. A goal-orientation on the other hand focuses on the achievement of personal goals, such as personal best times, thus indicating that success is relative to an individual's own performance in comparison with past performances and personal future aspirations (Daniels, Sincharoen, & Campbell, 2005). However, the findings of this particular study should be considered with caution as the sample was minimally generalizable, nor was the measurement tool entirely valid. These findings do however offer a consideration for potential program design as they are similar to other recommendations that have come from the more valid and reliable articles discussed throughout this review.

Similarly, Duda (1988) conducted a study to determine the relationship between social comparison-based goals, identification with mastery, and select motivated behaviours in recreational sports. More particularly, the research aimed to examine whether goal-perspectives were related to gender. The results of the study indicated that students who emphasized a mastery approach to sport goals were more likely to continue in sport longer and practice it more in their free time (Duda, 1988). Furthermore, recreational sport male and female participants differed in the emphasis they placed on ego and task involvement. Caution should be taken with this finding as the questionnaire was designed for the purposes of this study, and was not proven valid or reliable prior to its use. However, this finding will be further discussed below in Duda (1989) and Abrahamsen, Roberts, and Pensgaard (2008) and supports additional valid and reliable research produced in later years. Furthermore, White and Zellner (1996) replicated findings of female task orientation in a relatively large sample of high school, intercollegiate, and college-aged recreational athletes, which they stipulated is actually correlated with a lower likelihood of experiencing concentration disruptions prior to or during performances, and greater success in sport (White & Zellner, 1996).

From another perspective, Parsons and Betz (2001) considered young female athletes, their reasons for participating in/leaving sports, and locus of control, among other topics, which will be omitted from this review due to the intentions of the present research. In regards to locus of control, two domains were considered: personal efficacy and interpersonal control, which were assessed with measures carrying adequate validity and reliability. The study found that participation in sports and physical activity was consistently related to levels of personal efficacy. Not surprisingly, the higher the individual's self-perceived levels of personal efficacy were in that sporting domain, the greater their degree of participation (Parson & Betz, 2001). Therefore, the more control an athlete perceives they have in their respective sport, particularly toward their own performance, the more likely they are to stay involved in that sport.

Finally, a study by Weinberg and colleagues (2000) considered motivations for youth sport participation and continuation, more closely examining intrinsic and extrinsic motivational factors. Eight hundred and twenty-two boys and six hundred and fifty girls from the United States, Australia, and New Zealand participated in the three-part questionnaire that yielded some interesting gender comparison results. Firstly, intrinsic reasons including "having fun" and "improving my skills" were the two top reasons both male and female athletes gave for participation in competitive sports. Secondly, males reported being more motivated by the competition itself, whereas females reported favouring reasons such as social-affiliation and improvement/maintenance of fitness (Weinberg et al., 2000). Thus, the female interests in fun, fitness, and teamwork should be promoted in youth sport activities in order to increase and maintain participation, facilitate lessons, and cater to gender psychological perspectives.

The role of social environment.

As indicated above, the social environment is said to have an impact on sport participation, motivation, and other psychological aspects. It was stated that in general, many of the CSIA courses in which women are coached are mostly male dominated. As such, the male athlete perspective towards females participating is important. Hypothetically speaking, if the males in courses are supportive towards female involvement, it would be hypothesized that the female athletes would experience higher levels of peer support in that particular environment, and perhaps higher levels of self-esteem regarding ski participation. Although this hypothesis is speculative, Andre and Holland (1995) considered male and female athletes and non-athletes to compare attitudes towards each other. It was reported that the male athlete group as a whole carried more traditional attitudes towards women than male non-athletes did, while female athletes did not differ from female non-athletes' perceptions towards women. Another study by Miller and Levy (1996) investigated the differences in gender role conflict between female athletes and female non-athletes. Miller and Levy (1996) noted that female athletes are generally socialized into sport differently than non-athletes are. For example, they offered that female athletes may be socialized into sport through parental encouragement, and thus they may have positive role models in sport who promote participation (Miller & Levy, 1996). Ninety-six female non-athletes and seventy-six NCAA Division I female athletes participated in this self-report questionnaire study. Miller and Levy (1996) found that higher physical appearance self-concept, higher masculinity, and lower femininity were associated with athletic involvement. Correlations in sport participation and positive parental support for sport involvement were also significant. It was further noted that female athletes held a higher body image satisfaction than female non-athletes did. Overall, the researchers concluded that having positive social support, including parents who participate(d) in sports, and other sport role models, mitigate some of the issues females experience regarding gender role conflict (Miller & Levy, 1996). Furthermore, Brown and colleagues (1989) reiterated the influential role of parents and peers in athlete continuity:

> Those who received more encouragement and relative support for their involvement, who perceived that their significant others viewed sport as an appropriate form of social participation for adolescent females, and who reported increasing support for their participation as they grew older had stronger patterns of continuity than their counterparts who received less positive influences. (Brown, Frankel, & Fennell, 1989, p. 407)

It is clear that an athlete's social environment has an impact on the athlete's involvement in sport. Akyüz, Agar, Akyüz, and Dogru (2016) also support this by classifying the social environment as externally motivational for the female athlete, particularly as a key reason for why a sport becomes preferred for athlete participation. Furthermore, Eccles and Harold (1991) conducted two longitudinal studies with children and adolescents, respectively. The results of this study reported the existence of "consistent and strong gender differences in children's ratings of their own ability in sport and of the importance they attach to the sport domain" (Eccles & Harold, 1991, p. 29).

The coaching role within sport also takes an important role in athlete performance, attitudes, and participation. Abrahamsen, Roberts, and Pensgaard (2008) documented a difference in female and male athlete's focus, determining that males tend to be more ego-oriented in sport, while females tend to be more task-oriented. They further stated: "when coaches are more prone to be competitive and focus on ego involving criteria of success, female athletes experience greater concentration disruption" (Abrahamsen, Roberts, & Pensgaard, 2008, p. 460). Thus, it is projected that coaches who are primarily focused on adopting performance criteria in their interactions with elite female athletes, that these athletes are likely to experience higher levels of performance worries and more disruptions in concentration. As a result, they recommend that coaches employ more of a mastery criteria/task-oriented strategy, which consequently enables female athletes to better cope with the anxiety that may surround their sport (Abrahamsen, Roberts, & Pensgaard, 2008). Furthermore, they stipulate that this motivational climate may not be entirely enough, but also requires a focus on enhancing positive beliefs regarding individual abilities in each athlete. As a consequence, female athletes are likely to experience less stress and more enjoyment (Abrahamsen, Roberts, & Pensgaard, 2008).

A study by Duda (1989) furthers the importance of task-orientation for females in sport through the consideration of male and female high school athletes. As reportedly consistent with past research, Duda (1989) claims that:

> Females were more task oriented and males were more ego oriented in sport. These results suggest that there may be some distinctions in the way male and female high school athletes tend to construe their level of competence and process their success and failure experiences. (p. 331)

More particularly, females tended to view athletics as a context in which working with others is supported and significant toward motivations of trying their best. On the other hand, males perceived the competitive spirit and the importance of winning at all costs of primary importance (Duda, 1989). Similar findings were noted by Magyar and Feltz (2003) regarding task orientations and mastery climate. One hundred and eighty competitive adolescent female volleyball players completed questionnaires regarding motivational climate, sport confidence sources, and goal orientations. This correlational study identified that task orientation and perceptions of a mastery climate were, indeed, positively associated with adaptive social/environmental sources, as well as sources of sport confidence. An ego orientation, on the other hand, was associated with maladaptive sources of sport confidence. Thus, Magyar and Feltz (2003) concluded that establishing a mastery climate through coaching can support the development of self-confidence in their athletes, although further research of a more longitudinal nature is recommended.

Additional recommendations.

One of the perhaps more significant recommendations discussed in the literature came from Eccles and Harold (1991). Based on their research, they suggest the following:

> Interventions are needed that raise females' confidence in their ability to do well in sport activities and that raise the value, and reduce the psychological cost, they attach to engaging in sport activities. Such interventions might include: (a) attributional retraining for the females, and the adults who interact with the females around sport, (b) skill training in a positive affective environment that stresses cooperation and social interaction rather than competition, and (c) education regarding the value of sport for physical health and social interaction. (Eccles & Harold, 1991, p. 31)

On this note, Hanrahan and Cerin (2008) suggest "it may be advantageous to focus interventions designed to enhance task orientations on individual sport athletes" (p. 511). This statement was backed through a highly valid and reliable study that investigated one hundred and eight male and one hundred and sixty-four female athletes in Australia between the ages of twelve and seventy-four. The results of their questionnaire study indicated that females had a stronger task orientation than males, as previously mentioned in a number of the studies described above. However, a significant finding was noted regarding goal-achievement orientations in that individual sport athletes held a higher ego-orientation than team sport athletes did (Hanrahan & Cerin, 2008). As such, in a sport like Alpine skiing, a focus on task orientation in female athletes should be further emphasized, across all levels of competition, from recreational to elite skiers.

Programs Directed Towards Coaching Women

In order to conclude this literature review, I wanted to present some common themes seen across programs around the world that are specifically directed toward coaching women. However, I encountered a major issue in this part of the research as not many programs have something in place for targeting female biomechanical, physiological, and psychological development. Most programs are aiming to increase participation numbers by escalating the number of opportunities available for participation (e.g. Hockey Canada Esso Fun Days and World Girls Hockey Weekend, USA Ultimate Girls' Ultimate Movement (GUM), and the Women's Sports Foundation), while others have made some female-specific training modifications on a smaller scale but do not have female-specific programs in place (e.g. CrossFit). Another issue I encountered in my research for this section was that many of the programs state goals and/or objectives without specifying academic reasons for those goals, nor the plan of action for how they are going to achieve those goals (e.g. FIFA Women's Football Development Programs and Guidelines). That being said, I've included two programs below that illustrate some promising steps forward: Soccer Canada's Women's Excel Program and Women Sport Australia (WSA).

Soccer Canada – Women's Excel Program (Pathway Program – "Your Goals, Our Game"

- Goals of the program include: "To achieve consistent podium performances by our Women's National Team", "To create an aligned talent structure and system that progresses more top players to the Women's National Team and more often" and "To align community, regional and provincial/territorial talent development programs with the EXCEL talent pathway"
- It uses a "4 corner" approach, focusing on the development of female athletes from a physical, mental, technical/tactical, and social/emotional standpoint.
    - Physical aspects include: soccer specific training, optimal health care, female specific training, and a longitudinal development model
    - Mental aspects include: biofeedback training, attentional control, arousal regulation, consistency, and resilience.
- Opportunities for participation are available to athletes as young as those participating at the U-13 level and are designed to carry athletes through University
- It does state that this opportunity is designed for players who show promise at an early age, and thus it specifically targets the best players at various age groups, which could be considered as a limitation to this program
- Focuses on physical training aspects and boasts a "player-centered" approach in which it tries to support self-awareness, personal development, self-sufficiency, and cognitive abilities
- Seems to be one of the most explicit programs catered towards female development and provides some academic support with a detailed progression of how to get there
- For more information, please visit: http://www.canadasoccer.com/files/CanadaSoccerPathway_WomensEXCELProgram_TechnicalOverview_201509.pdf

Women Sport Australia (WSA)

- This not-for-profit organization aims to support and promote leadership in women and girls within sport and physical activity by targeting perceived barriers, such as equal pay, access to competition and training facilities, equal media time, and equal access and facilitation toward leadership and mentorship opportunities
- **WSA focuses on psychological standpoints of women, particularly pertaining to leadership, confidence, motivation, and enjoyment of sport and physical activity participation**
- Sporting organizations become members of WSA and thus receive assistance through funding and various administrative functions
- For more information, please visit: http://www.womensportaustralia.com.au/

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Appendix

The following two tables illustrate the two programs implemented in the study by Myer and colleagues (2006) as shown in the article on pages 347-348.

TABLE 1. Plyometric training at weeks 1, 3, and 6.

Plyometric training	Time*	Reps
Week 1		
Athletic position		5
Wall jumps	15	
Squat jumps	10	
Tuck jump (with thighs parallel)	10	
Line jumps (side to side)	10	
Line jump lateral max vertical		5
Lunge jump	10	
180° Jumps (height)	15	
Broad jump vertical + step†		8
Bounding in place	20	
Forward jumps over barriers + step†		6
Forward barrier jumps with middle box + step†		6
Box drop max vertical + step†		10
Box drop + step†		10
Week 3		
Wall jumps	15	
Squat jumps	15	
Tuck jump (with abdominal crunch)	15	
Tuck jump (with butt kick)	15	
Barrier jumps (front to back)	15	
Barrier jumps (side to side)	15	
Hop, hop, hop-athletic position + step†		6
180° Jumps (height)	15	
Broad jump, jump, jump vertical + step†		6
Bounding for distance		6
Lateral barrier hops with staggered box reaction		6
Back drop-box touch-max vertical + step†		10
Lateral box drop max vertical		5
Power steps		8
Week 6		
Squat-tuck jumps	12	
Barrier hops flat (front to back)	12	
Barrier hops flat (side to side)	12	
Crossover hop, hop, hop-athletic position + step†		10
180° Jumps (height)	15	
Broad jump, jump, jump vertical + step†		6
3 Barrier hop-reaction (3-way)		3
Forward-backward hops over barriers + step†		6
Box drop-180°-box drop-max vertical + step†		8
Box drop-180° + step†		8
Lateral box drop-broad jump + step†		6
Box drop max vertical-broad jump + step†		6
Approach max vertical		4
Crossover step-ski stop max vertical		4

* Time in seconds.
† Exercise ends with a quick reaction step.

TABLE 2. Core stability training at weeks 1, 3, and 6.

Core stability training	Time*	Reps
Week 1		
Deep hold position		5
Box butt touch		8
Line jump (forward)-deep hold		8
Line jump (lateral)-deep hold		4
Box drop-deep hold		10
Single leg squat-deep hold		6
BOSU(F)† deep hold	5	8
BOSU(F)† drop squats		8
BOSU(R)‡ jump stick landing-deep hold		10
BOSU(R)‡ both knees deep hold	20	
BOSU(R)‡ crunches		35
BOSU(R)‡ swivel crunch (feet planted)		40
BOSU(R)‡ single leg pelvic bridges		12
BOSU(R)‡ supermans		12
Week 3		
BOSU(F)† drop stick-deep hold		10
BOSU(F)† deep hold partner perturbations	20	
Box drop (lateral)-deep hold		4
Single leg line hop (front-back)-deep hold		8
Single leg line hop (side-side)-deep hold		8
Single leg squat-heel touches		10
Swiss ball both knees deep hold	20	
BOSU(R)‡ single leg step-stick deep hold		6
Double crunch		25
Table double crunch		15
Table double swivel crunch		8
Table reverse hyperextensions		12
BOSU(R)‡ lateral crunch		10
BOSU(R)‡ swimmers		10
Week 6		
Double BOSU(F)† deep hold (partner perturbations)	10	5
BOSU(F)† drop single leg airex stick deep hold		5
BOSU(R)‡ single leg deep hold partner ball toss	25	
Swiss ball both knees deep hold (partner perturbations)	20	
BOSU(R)† single leg (4 + way) hop stick deep hold		8
BOSU(F)‡ single leg ball pick up		8
Airex walking lunges		5
BOSU(F)† single leg squats		8
BOSU(F)† single leg deep hold (partner perturbations)	30	
Straight leg lifts with toe punch		15
Straight leg lateral double crunch		12
BOSU(R)‡ double crunch		15
BOSU(R)‡ opposite swivel crunch (feet up)		12
Swiss ball reverse back hyperextensions		12

* Time in seconds.
† BOSU flat side up.
‡ BOSU round side up.