Countermovement jump height in national team athletes of various sports: a framework for practitioners and scientists

CMJ height in national team athletes

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Abstract

Purpose: To quantify possible differences in countermovement jump (CMJ) height across sport disciplines and sex in national-team athletes. **Methods:** In this cross-sectional study, 588 women (23 ± 5 y, 66 ± 8 kg) and 989 men (23 ± 5 y, 82 ± 12 kg) from 44 different sport disciplines (including 299 medalists from European Championships, World Championships and/or Olympic Games) tested CMJ on a force platform at the Norwegian Olympic Training Center between 1995 and 2018. **Results:** Athletic sprinting showed the highest values among the men (62.7 ± 4.8 cm) and women (48.4 ± 6. cm), clearly ahead of long jump/triple jump (mean difference, ±90%CL: 6.5, ±5.0 and 4.3, ±4.1; very likely and likely; moderate) and speed skating sprint (11.4, ±3.1 and 7.5, ±5.5 cm; most likely and very likely; very large and moderate). These horizontally-oriented sports displayed superior results compared to more vertically-oriented and powerful sports such as beach volleyball, weightlifting and ski jumping, both in men (from 2.9, ±4.7 to 15.6, ±2.9 cm; small to very large; possibly to most likely) and women (5.9, ±4.8 to 13.4, ±3.4 cm; large to very large; very likely to most likely), while endurance sports and precision sports were at the other end of the scale. Overall, the men jumped 33% higher than the women (10.3, ±0.6 cm; most likely; large). **Conclusions:** This study provides practitioners and scientists useful information regarding the variation in CMJ height among national-team athletes within- and across sport disciplines.

Keywords: Vertical jump; physical capacity; national team athletes; force platform testing; power.

Introduction

Vertical jump tests have been a cornerstone of the fitness test battery for numerous practitioners and sports scientists over the years due to their simplicity and practicality. Dudley Allen Sargent introduced the famous test for assessing jump height bearing his name already in 1921.[1] His pioneering work was followed by seminal studies in the 1960s, 70s and 80s by Cavagna et al.,[2] Asmussen & Bonde-Petersen,[3] Komi & Bosco,[4] Bosco et al.,[5] establishing applicable protocols for varying vertical jump modalities and physiological indicators for their measurements. Bilateral vertical jump is the exercise modality where the highest anaerobic power output values are obtained,[6] although a direct relationship between jump height and power output is confounded by body mass, push-off distance, optimal loading and individual force-velocity profile.[7]

The countermovement jump (CMJ) test has been the most popular and commonly reported vertical jump test in research literature the last 2-3 decades. However, differences in apparatus (force platforms, infrared platforms, contact mats, accelerometers, linear position transducers, video or motion tracking systems), software, testing procedures (e.g., with or without arm swing) and calculation methods across studies can cause very large jump height differences, making it challenging to distinguish excellent results from mediocre. Although CMJ assessments can be performed in multiple ways, stationary force platforms are considered gold-standard for accurate jump height computation when using the impulse method.[8,9]

The validity of the CMJ test has been the subject of much debate within varying sport communities. Some argue that only sport-specific tests are useful, while others suggest that less externally valid (i.e., non-specific) tests also can provide a clearer understanding of underlying causes and physical performance factors.[10] This information can in turn be used as framework for individual and collective training prescriptions, informing recovery strategies and load management. As a point of departure for validity determination, knowledge regarding the variation in CMJ height within- and across sports would be useful for practitioners and scientists.

Very few studies have examined CMJ performance in elite athletes across a variety of sports. Laffaye et al.[11] reported sex and sport-specific differences based on CMJ performance with free arm swing in 189 male and 84 female elite athletes involved in college and professional sports (primarily football, basketball, baseball, and volleyball). Centeno-Prada et al.[12] outlined percentiles for squat jump (SJ), CMJ with no arm swing (akimbo) and Abalakov jump performance based on 323 male elite athletes from 10 different sports. Giroux et al.[13] examined the effect of elite sport background on the force-velocity relationship in SJ based on 95 elite athletes in cycling, fencing, taekwondo and athletics sprinting. Finally, Jiménez-Reyes et al. [14] explored the relationship between vertical and horizontal force-velocity-power profiles in various sports and levels of practice based on SJ performance in a large number of participants. The best performance level category in this study (elite/professionals, n = 182) were represented in five different sports. Indeed, more research is required to get a clearer overview of the vertical jump capacity continuum in world-class athletes across a variety of sports.

The Norwegian Olympic Training Centre is a standard testing facility for an extensive number of national team and world-class athletes from different sports. A database with ~ 30 000 CMJ test results that has been collected over several decades under standardized procedures provides an excellent foundation for exploring fundamental aspects of vertical jump capacity in high-level performers. Therefore, the aim of this study was to quantify possible differences in CMJ performance as a function of sport discipline and sex among national-team athletes. Such a framework is useful for practitioners and scientists when diagnosing individual athletes and prescribing training programs targeted to develop explosive force in the lower limbs.

Methods

Subjects

This cross-sectional study included CMJ tests results of 1577 athletes (989 men and 588 women). All participants were Norwegian national-team athletes, i.e., represented Norway in international senior competitions, and 299 of the athletes were medalists from the World Championships, European Championships and/or Olympic Games.

Table 1 presents sample size, athlete characteristics and CMJ height across the 44 included sports/disciplines. A minimum of five athletes were required for a sport/discipline to be included. For clarity, and to keep the number of comparisons within reasonable limits, the sports/disciplines were grouped into seven categories (mainly based on structural traits and internal logic of action situations): strength & power sports, team sports, downhill winter sports, combat sports, endurance sports, precision sports, and others.

Table 1 about here

This study was based on pre-existing data from quarterly or semiannual testing that these athletes performed for training purposes, and thus, no informed consent was obtained. Because of the newly implemented General Data Protection Regulations (GDPR) by the European Union, all data were anonymized. This study was reviewed by the Norwegian Data Protection Authority (reference 600562) and approved by the ethics committee at the Faculty of Health and Sport Sciences, University of Agder (reference 19/08671).

Methodology

All included athletes were tested at the Norwegian Olympic Training Centre in the time period 1995-2018. The CMJ tests were performed on a 122 x 62 cm force platform (AMTI, model OR6-5-1, Watertown, USA). The system setup and jump height calculation procedures were in accordance to the guidelines outlined by Street et. al.[9] More specifically, this method is based on the impulse-momentum relationship, where the net vertical force acting on the athlete prior to take-off is integrated in order to estimate take-off velocity. This take-off velocity is in turn used in a projectile motion equation for jump height computation. Force data were sampled at 1000 Hz for 5 s with a resolution of 0.1 N. The data were amplified (AMTI Model SGA6-3), digitized (DT 2801) and saved to dedicated computer software (Biojump, Norway).

A standard warm up program was completed prior to testing, consisting of 10-15 min easy jog, followed by 3-4 strides and 3-5 trial jumps with increasing intensity. Each athlete was weighed on the force platform for system calibration before testing. They then performed 4-6 jumps with 45-60 s recovery between each trial until jump height stabilized. All jumps were performed with hands placed on the hips. The depth of knee and hip flexion during each jump were individually determined by the athletes. Best result for each athlete was retained for analysis. Coefficient of variance (CV) for CMJ height with these procedures and setup is ~3%.[15] Data from a single athlete was only included in one category for each analysis. That category was the athlete's affiliation on the day of his/her best CMJ test result.

The experimental setting, procedures and conditions were consistent throughout the 23-year data collection period, and the test results were not negatively affected by other tests. Regarding nutrition, hydration, sleep and physical activity, the athletes were advised to prepare themselves as they would for a regular competition, including no high intensity training the last two days before testing.

Statistical analysis

Data are reported as mean and SD. Magnitudes of differences across category means were assessed by standardization (mean difference divided by the harmonic mean of the SD of the compared groups). The thresholds for assessing the observed difference in means were 0.2, 0.6, 1.2, 2.0 and 4.0 for small, moderate, large, very large and extremely large, respectively.[16] To make inferences about true values of effects, non-clinical magnitude-based decisions rather than null-hypothesis significance testing was used.[16] Magnitudes were evaluated mechanistically: if the confidence interval overlapped substantial positive and negative values, the effect was deemed unclear; otherwise effects were deemed clear and shown with the probability that the true effect was substantial using the following scale: 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; > 99.5%, most likely.[16] A purpose-built excel spreadsheet for combining outcomes from several subject groups was used to calculate effect magnitudes, confidence limits (CL) and inferences.[17] To analyse sex differences across the sport categories with unbalanced data, a linear mixed model was conducted using the MIXED procedure in SAS 9.4 Software (SAS Institute, Cary, NC, USA). Category, sex and category • sex were included as fixed effects, while sport discipline was included as a random effect. In addition, heterogeneity was specified in the covariance structure of the residual matrix for category • sex. The sport disciplines represented by one sex only were excluded from the sex difference analysis. The relative sex differences were calculated as a percentage of female results.

Results

To keep this section within reasonable limits, only a summary of the results is presented. However, additional comparisons across sports/disciplines can be performed by inserting data from Table 1 into Hopkins' spreadsheet.[17]

Figure 1 about here

Figure 1 shows mean ± SD for CMJ height in men and women across sport categories. Overall, strength & power sport athletes displayed the highest values (51.9 ± 6.9 cm and 39.6 ± 5.1 cm for men and women, respectively), clearly ahead of team sports (mean difference, ±90%CL for men and women: 9.7, ±1.2 and 8.5,±1.0 cm), downhill winter sports (9.8, ±1.4 and 6.7, ±1.3 cm), combat sports (12.3, ±1.3 and 11.2, ±1.3 cm), endurance sports (15.8, ±1.4 and 11.6, ±1.3 cm) and precision sports (16.9, ±1.8 and 15.2, ±2.1 cm). In terms of magnitude-based decisions, all these differences were most likely and ranged from large to very large. The highest observed CMJ (akimbo) heights out of ~30000 measurements since 1995 were 72 and 58 cm for men and women.

Interestingly, horizontally-oriented strength & power sports such as athletic sprinting, long jump/triple jump and speed skating sprint achieved superior CMJ results compared to more vertically-oriented sports such as beach volleyball, weightlifting and ski jumping, both in men (from 2.9, ±4.7 to 15.6, ±2.9 cm; small to very large; possibly to most likely) and women (5.9, ±4.8 to 13.4, ±3.4 cm; large to very large; very likely to most likely) (Table 1). No substantial differences in jump height were observed when comparing weightlifting, beach volleyball and ski jumping.

Beach volleyball showed the best CMJ results among the analysed male team sports, clearly higher than volleyball (4.1, ±2.3 cm; very likely; moderate), handball (6.0, ±2.1 cm; most likely;

moderate), ice hockey (6.9, ±2.0 cm; most likely; large), soccer (8.2, ±2.2 cm; most likely; large) and all other male team sports (8.4, ±2.4 cm to 13.1, ±3.1 cm; most likely; large to very large). Beach volleyball also exhibited the highest mean values among the analysed female team sports, clearly ahead of volleyball (2.7, ±3.1 cm; likely; small), soccer (3.9, ±2.6; very likely; moderate), indoor bandy (7.1, ±2.8; most likely; large) and all other female team sports (7.2, ±2.9 to 12.7, ±5.2 cm; most likely; large to very large), except that the difference between beach volleyball and handball was unclear.

Table 2 about here

Table 2 shows sex differences in CMJ height across the analysed categories. Overall, the mean sex difference ranged from 8 to 12 cm across sport categories, and male athletes in this study jumped on average 33% higher than females.

Discussion

To the authors' knowledge, this is the most comprehensive study of CMJ performance in national-team athletes to date. Up to very large differences in jump height were observed across sport categories, and the variation across disciplines ranged from trivial to extremely large. Strength & power sport athletes obtained the highest values, while endurance and precision sport athletes showed substantially lower values. Athletes from horizontally oriented strength & power sports displayed superior CMJ values compared to those from sports in which vertical jumping is a primary competitive skill. Male athletes jumped on average ~ 33% higher than female athletes. The current data from a large sample of national team athletes tested under identical conditions quantifies the variation in CMJ height within- and across sport categories and disciplines.

Indeed, the validity of the CMJ test varies across sport disciplines. While vertical jumping is directly related to competitive performance in some sports, such skills are not crucial for performance in other sports. It is beyond the scope of this study to establish the validity of CMJ testing for each of the 44 sport disciplines presented, but it is reasonable to argue that CMJ testing is more relevant for sports with high group mean values. Among the analyzed sport disciplines, mean CMJ height was in the range 30-63 cm for men and 22-48 cm for women, with athletic sprinting and long jump/triple jump displaying the highest values. In a similar study of vertical jump capacities including 10 different sport disciplines, Centeno-Prada et al.[12] also observed that athletics sprinters displayed the best scores. Jiménez-Reyes et al.[14] analyzed SJ performance in 13 different sport disciplines and reported that weightlifting, rugby and athletic sprinting were the best performers. Because bilateral vertical jump is the exercise modality where the highest anaerobic power output values are obtained,[6] it is not surprising that strength & power sports are at the upper end of the scale. Strength/power and endurance capacities are determined by different genetic traits, and it is therefore expected that endurance sports are located at the lower end of the CMJ performance range. Moreover, longitudinal endurance training impairs strength and power adaptations.[18]

Interestingly, sport disciplines such as sprinting, long jump/triple jump, speed skating sprint and bobsleigh achieved superior CMJ results compared to sports such as beach volleyball, weightlifting and ski jumping, despite the fact that the first sport disciplines must orient their ground reaction forces more horizontally than the latter disciplines during their sport-specific exercise execution. Large correlation values are observed between sprint and vertical jump performance in heterogeneous subsets of athletes,[15,19,20] reflecting the need for well-developed explosive force capacities in the lower limbs in these modalities. However, large correlations do not imply causation. Due to the cross-sectional approach of this study, the presented results cannot be extrapolated to training adaptations and possible transference between vertically and horizontally oriented exercises. The higher the level and homogeneity of athletes' groups, the lower the association between horizontal and vertical profiles.[14] While novice athletes will likely improve their performance with basic prescription, an increase in vertical jump performance does not necessarily translate to better sprint performance (and vice versa) in elite populations.

The present results revealed that team sports such as beach volleyball, volleyball and team handball possessed superior CMJ performance compared to soccer, ice hockey and bandy. In volleyball and beach volleyball, the top of the net is 2.43 and 2.24 m above ground level for men's and women's competition, respectively, requiring considerable vertical reach during spikes and blocks. Jump shots and block actions are also frequent actions in handball, depending on playing position. Indeed, substantial differences in CMJ performance can be observed within certain team sports, particularly in handball,[21] reflecting the varying demands across playing positions. Moreover, vertical jump capacity may be sensitive to the varying season times. Haugen et al.[22] observed that CMJ and sprint results obtained in soccer players' off-season were likely better than those for pre-season. Similarly, Los Arcos et al.[23] reported negative effects of a 9-week pre-season conditioning program on CMJ and sprint performance. Because the energy demand in most team sports are covered by both aerobic and anaerobic processes, explosive actions may be related to constraints of overall team conditioning. Total training load is typically greatest in pre-season, ahead of in-season and off-season, and the accumulation of training volume during pre-season can impair the improvement of anaerobic fitness variables believed to be important for the on-field team sport performance.[23]

The sex difference in CMJ height across the analyzed categories was in the range 8-12 cm, and male athletes in this study jumped on average 33% higher than females. This relative sex difference is similar to the sex difference observed in weightlifting world record performances.[24] These are in turn considerably larger than the sex differences observed in world record performance for most sprint, middle- and long-distance events.[25] Similarly, VO_2max values are typically ∼15% higher in men than in women among elite distance runners and cyclists, while sex differences for peak acceleration power normalized to body mass ($W \cdot kg^{-1}$) in world-class sprinting and cycling seem to be ~17 and 25%.[6] However, women are approximately 52 and 66% as strong as the men in the upper and lower body, respectively,[26] corresponding to the sex differences observed in world record performance within powerlifting exercises. The sex difference in muscular strength in equally trained men and women is almost entirely accounted for by the difference in muscle mass.[27] Overall, the higher the maximal strength component, the larger the sex difference. Because vertical jump performance is an integration of both force and velocity components,[28] it is reasonable that the sex difference in CMJ performance falls between strength- and velocity-oriented disciplines.

The highest individual akimbo CMJ heights in this study were 72 and 58 cm for men and women. However, caution must be made when comparing these results to other studies. The akimbo CMJ assessments in this investigation were obtained by a stationary AMTI force platform, and the impulse method was used for jump height calculations. Practitioners and scientists must be aware that the combination of different measurement procedures and apparatus can cause jump height differences many times greater than performance changes caused by years of conditioning. Errors in force plates applications may occur because of improper installation, calibration routines and data acquisition settings. Failing to follow the guidelines outlined when assessing jump height on a force platform can lead to average errors as large as 26%.[9] Similarly, CMJ height results based on the present impulse method are not directly comparable with those based on the flight time method due to differences in center-of-mass position at measurement initiation.[29] Moreover, comparison of vertical jump height results without consideration of the varying jumping modalities can cause a lot of confusion. Most athletes jump slightly higher during CMJ than SJ, and arm swing create even larger differences than akimbo jumps.[30] Adding to the problem, the use of arm swing has been found to increase the jump height of the men significantly more than that of women, and changes in jumping modality affect men and women differently.[30] Because the magnitude of jump height differences across jump modalities seem highly individual, it is challenging to develop correction factors. However, future studies should elucidate the effect of varying apparatus (force platforms, infrared platforms, contact mats, accelerometers, linear position transducers, video or motion tracking systems) on vertical jump height.

Some other study limitations should also be addressed. Firstly, although the best test result for each athlete was retained for analysis, it is reasonable to assume that not all athletes were assessed at their maximum during the season in terms of peak CMJ performance. Secondly, the standardized warm-up procedures may not have been optimal for all athletes. Moreover, our grouping of sport disciplines into the six categories can be questioned, as some sports may bear several "labels". However, there is no consensus on how sports should be categorized. Practitioners and scientists classify sports in different ways, depending on perspectives, individual preferences, data sample (size) and context. We argue that the present categories reflect the distribution of athletes in this study and that they make sense for most readers. Finally, CMJ height in isolation may have limited informative value for individual training prescription foundation. Analyzing the underlying force-velocity profiles could facilitate better comparisons within and between athletes, as identical jump heights can be achieved with different force-time curves.[14,31] These issues should be further explored in future studies of elite athletes.

Practical applications

The current investigation provides an overview of the CMJ performance variety in national-team contestants. Such background information is useful for practitioners and scientists involved in physical testing of athletes and may serve as framework for athlete diagnosing and training program prescriptions targeted to develop explosive force in the lower limbs.

Conclusions

In this cross-sectional study of national-team athletes, up to very large and even extremely large differences in CMJ height were observed across sports. Strength & power sports obtained the highest values, while endurance and precision sports showed substantially lower values. Interestingly, horizontally-oriented strength & power sports (i.e., athletic sprinting, long jump/triple jump, speed skating sprint and bobsleigh) exhibited superior CMJ values compared to more vertically-oriented powerful sports (i.e., ski jumping, beach volleyball and weightlifting), while endurance and precision sports were located at the other end of the range. Male athletes jumped on average ~33% higher than the women.

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Figure 1. Countermovement jump height (CMJ; mean ± SD) across sport categories. Strength & power sports: Athletic sprinting, long jump/triple jump, speed skating sprint, athletics throwing, weightlifting and ski jumping. Team sports: Beach volleyball, volleyball, handball, ice hockey, soccer, indoor bandy and bandy. Downhill winter sports: Alpine skiing, freestyle skiing, skicross, snowboard and Telemark skiing. Combat sports: Wrestling, judo, karate, taekwondo, kickboxing, fencing and boxing. Endurance sports: Speed skating all-round, swimming, cross-country skiing sprint, biathlon, cross-country skiing all-round and orienteering. Precision sports: Golf and curling.

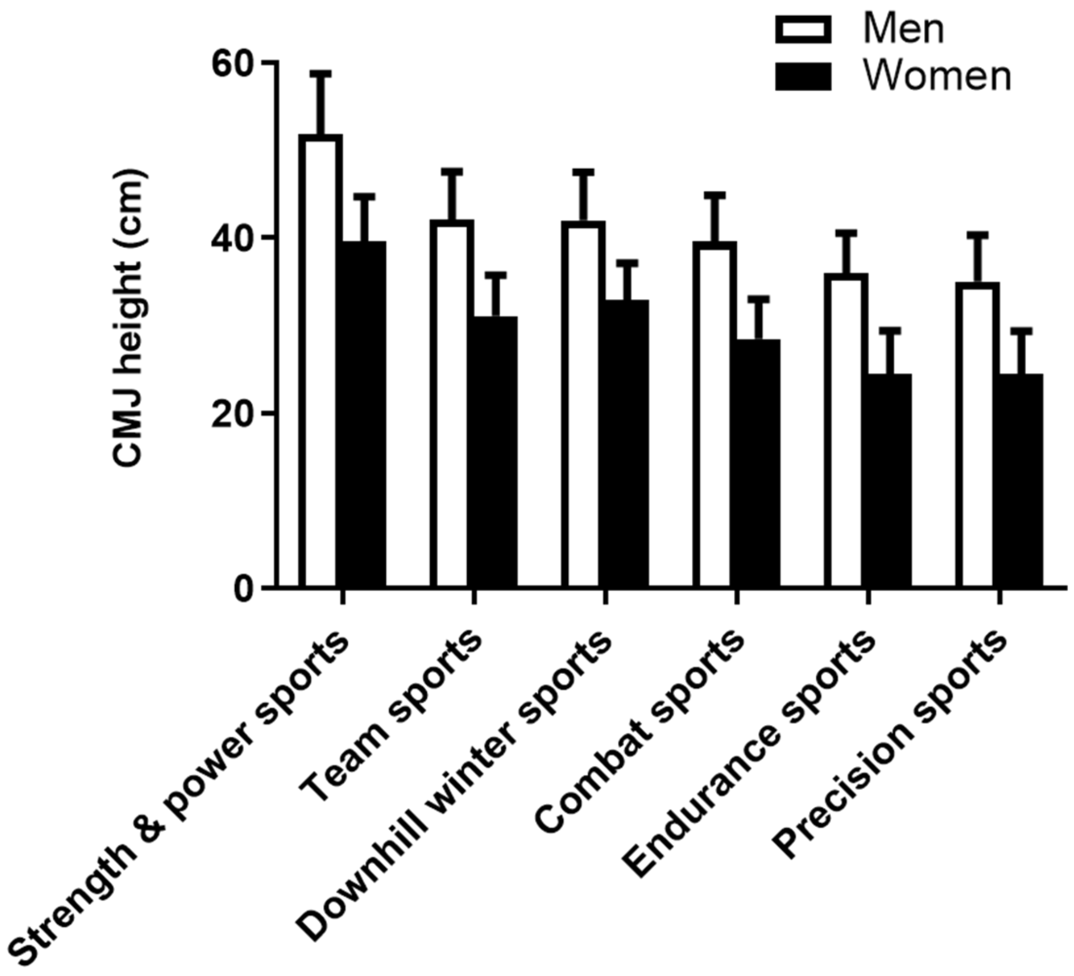

Table 1. Sample size, athlete characteristics and CMJ height (mean ±SD) across sport disciplines

	Men				Women			
Sport/discipline	***n***	**Age** *(y)*	**BM** *(kg)*	**CMJ height** *(cm)*	**n**	**Age** *(y)*	**BM** *(kg)*	**CMJ height** *(cm)*
Strength & power sports								
Athletic sprinting (100/200 m)	13	25 ± 4	79 ± 10	62.7 ± 4.8	11	24 ± 4	60 ± 5	48.4 ± 6.0
Long jump/triple jump	9	24 ± 4	81 ± 7	56.2 ± 7.4	11	22 ± 5	60 ± 5	44.1 ± 5.2
Speed skating sprint	19	24 ± 4	81 ± 8	51.3 ± 5.4	8	25 ± 5	68 ± 7	40.9 ± 7.0
Bobsleigh	18	26 ± 4	91 ± 9	50.0 ± 10.1				
Athletics throwing	20	23 ± 5	103 ± 15	48.5 ± 9.3	13	21 ± 4	76 ± 9	35.6 ± 4.6
Weightlifting	27	22 ± 3	91± 18	47.4 ± 7.4	15	22 ± 5	63 ± 11	35.8 ± 4.9
Ski jumping	26	24 ± 3	65 ± 4	47.1 ± 5.4	28	20 ± 4	59 ± 3	35.0 ± 3.6
Powerlifting					9	25 ± 6	65 ± 8	35.0 ± 7.8
Skeleton	8	24 ± 4	81 ± 7	38.9 ± 9.7				
Team sports								
Beach volleyball	38	26 ± 6	88 ± 9	48.1 ± 6.7	20	25 ± 4	71 ± 6	35.7 ± 6.6
Volleyball	43	22 ± 3	89 ± 8	44.5 ± 5.8	19	21 ± 3	71 ± 7	33.0 ± 4.9
Handball	83	22 ±4	92 ± 11	42.1 ± 5.4	68	25 ± 4	73 ± 7	35.5 ± 4.7
Ice hockey	136	24 ± 4	86 ± 8	41.2 ± 5.6	29	22 ± 4	66 ± 9	28.5 ± 4.8
Soccer	21	27 ± 3	87 ± 11	39.9 ± 3.3	95	24 ± 4	65 ± 6	31.8 ± 4.2
Indoor bandy	15	23 ± 3	72 ± 6	39.7 ± 3.5	24	22 ± 3	64 ± 5	28.6 ± 3.9
Bandy	73	22 ± 5	80 ± 9	39.5 ± 5.0	20	24 ± 7	68 ± 8	24.7 ± 4.4
Downhill winter sports								
Alpine skiing	25	27 ± 3	87 ± 8	44.9 ± 5.5	29	25 ± 3	67 ± 5	36.1 ± 4.5
Freestyle skiing	13	21 ± 3	71 ± 7	41.8 ± 7.1	6	21 ± 2	63 ± 9	32.5 ± 4.5
Skicross	6	24 ± 3	87 ± 7	41.5 ± 6.1	5	24 ± 2	70 ± 3	33.3 ± 3.4
Snowboard	42	21 ± 3	75 ± 10	41.0 ± 5.6	5	22 ± 2	63 ± 6	33.8 ± 3.7
Telemark skiing	24	21 ± 4	81 ± 7	40.9 ± 4.0	8	22 ± 3	63 ± 5	28.8 ± 3.4
Combat sports								
Wrestling	30	23 ± 3	80 ± 15	42.0 ± 6.6	12	20 ± 2	66 ± 10	28.2 ± 6.6
Judo	5	21 ± 2	72 ± 8	41.7 ± 4.8	5	21 ± 2	65 ± 5	28.8 ± 4.9

Karate	32	23 ± 4	75 ± 12	40.4 ± 6.0	5	22 ± 3	62 ± 4	30.5 ± 3.2
Taekwondo	30	22 ± 4	70 ± 10	39.9 ± 3.9	12	21 ± 5	62 ± 9	28.5 ± 4.9
Kickboxing	12	25 ± 7	71 ± 9	39.0 ± 3.3	8	25 ± 4	61 ± 3	28.1 ± 3.1
Fencing	6	23 ± 4	82 ± 10	38.0 ± 4.6	5	23 ± 5	65 ± 4	30.7 ± 5.1
Boxing	11	22 ± 2	74 ± 9	36.0 ± 4.6	17	23 ± 5	61 ± 6	25.1 ± 3.0
Endurance sports								
Speed skating all-round	24	23 ± 3	78 ± 6	41.6 ± 6.3	11	22 ± 3	66 ± 7	34.2 ± 3.9
Swimming	15	22 ± 4	79 ± 11	39.7 ± 4.1	5	19 ± 3	64 ± 4	31.1 ± 4.5
Cross-country skiing sprint	8	25 ± 5	78 ± 6	37.0 ± 3.7	5	23 ± 3	65 ± 5	28.4 ± 2.6
Rowing	11	26 ± 5	90 ± 9	36.8 ± 7.4				
Biathlon	15	26 ± 4	78 ± 7	33.4 ± 3.0	14	25 ± 4	63 ± 6	25.1 ± 3.8
Cross-country skiing all-round	14	26 ± 3	76 ± 6	33.1 ± 3.3	15	27 ± 5	60 ± 6	26.3 ± 4.4
Road cycling	7	23 ± 4	80 ± 8	31.8 ± 4.5				
Orienteering	5	28 ± 5	74 ± 5	30.4 ± 3.8	5	29 ± 5	56 ± 7	22.8 ± 5.7
Precision sports								
Golf	21	20 ± 4	79 ± 10	35.0 ± 5.0	13	20 ± 5	65 ± 11	25.7 ± 3.9
Curling	16	33 ± 7	82 ± 11	35.0 ± 5.8	7	29 ± 5	66 ± 9	23.0 ± 6.5
Bowling	8	28 ± 4	77 ± 9	31.7 ± 4.1				
Others								
Athletics decathlon	5	23 ± 7	87 ± 10	51.3 ± 11.9	6	20 ± 5	64 ± 9	34.5 ± 5.3
Nordic combined	21	27 ± 4	70 ± 4	43.7 ± 4.5				
Figure skating					20	19 ± 2	55 ± 6	33.2 ± 4.2
Table tennis	19	23 ± 4	73 ± 7	35.9 ± 4.5				
Water skiing	15	24 ± 3	76 ± 10	35.3 ± 6.6				

BM = body mass, CMJ = countermovement jump

Table 2. Sex differences (mean ±90% CL) across sport categories

Category	Sex difference (cm)			
	Mean	*Lower*	*Upper*	*(%)*
Strength & power sports	12.4	11.0	13.0	31.1
Team sports	10.5	9.7	11.4	33.1
Downhill winter sports	9.2	7.8	10.6	28.0
Combat sports	11.4	10.1	12.7	40.3
Endurance sports	7.8	6.6	9.1	27.8
Precision sports	10.3	7.9	12.7	41.7
All	10.3	9.7	10.9	33.3

In terms of magnitude-based decisions, all sex differences were most likely and ranged from moderate to large. Strength & power sports: Athletic sprinting, long jump/triple jump, speed skating sprint, athletics throwing, weightlifting and ski jumping. Team sports: Beach volleyball, volleyball, handball, ice hockey, soccer, indoor bandy and bandy. Downhill winter sports: Alpine skiing, freestyle skiing, skicross, snowboard and Telemark skiing. Combat sports: Wrestling, judo, karate, taekwondo, kickboxing, fencing and boxing. Endurance sports: Speed skating all-round, swimming, cross-country skiing sprint, biathlon, cross-country skiing all-round and orienteering. Precision sports: Golf and curling.