Original Paper

Biomedical Human Kinetics, 17, 147–157, 2025
DOI: 10.2478/bhk-2025-0014

Vertical jumping power normative-reference values: Utilizing a large cohort of Canadian University students

Olivia N. Morassutti, Paula M. van Wyk, Adriana M. Duquette

Department of Kinesiology, University of Windsor, Canada

Abstract

Study aim: This study aimed to develop vertical jumping power normative-reference standards based on a large cohort of Canadian university students.
Material and methods: Data were collected from a sample of 960 male and female participants, aged 20 to 29 years (mean body mass index [BMI]: 24.44 ± 3.80). Participants performed the Sargent jump-and-reach test using a wall-mounted vertical jumping height scale, where vertical jump distance (VJD) was determined by subtracting standing reach height from vertical jumping reach height. An independent samples t-test was conducted to compare the means of all variables (i.e., absolute power, relative power, and VJD) and to test for statistical significance between sexes.
Results: Data from all variables were higher ($p < 0.05$) among male participants, including absolute power (W), relative power ($W \cdot kg^{-1}$), and VJD (m), and statistically significant differences between sexes were noted. Collected data facilitated the creation of sex-specific normative-reference standards including percentile rankings and seven performance classifications.
Conclusions: These norms will be instrumental in supporting the convenient and practical evaluation of vertical jumping power performance data and may even reduce the need for other, more exhaustive testing methods (e.g., Wingate Anaerobic Test).

Keywords: Anaerobic power – Vertical jump – Sargent jump-and-reach test – Absolute power – Relative power

Introduction

Anaerobic power provides immediate energy during periods of high-intensity, short-duration exercise lasting less than ten seconds (McArdle et al., 2010). It is generated using anaerobic energy sources (i.e., oxygen is not directly used) in skeletal muscle and is heavily dependent on the maximum amount of adenosine triphosphate (ATP) that is produced by the phosphocreatine (PC) system per unit of time (McArdle et al., 2010). While anaerobic power is a key component in assessing overall athletic ability, it plays a critical role in the performance of and success in specific athletic events (e.g., sprinting, jumping, weightlifting, etc.), where it is essential to generate power in a short period of time (McArdle et al., 2010). Anaerobic fitness, which is the capacity to perform activities and exercises that involve the use of anaerobic power, is closely associated with daily functional ability (Lelieveld et al., 2007). Anaerobic fitness is an essential component of performing everyday tasks that are short-term and intensive in nature, including climbing the stairs (Lelieveld et al., 2007; Takken et al., 2003). As such, poor anaerobic fitness can considerably impact daily functioning, making it more challenging to perform certain tasks, while ultimately affecting general fitness and health (Lelieveld et al., 2007; Takken et al., 2003). An example of a test that is used to quantify anaerobic power output is the Sargent jump-and-reach test (McArdle et al., 2010). This test measures vertical jump distance (VJD), which is the difference between standing reach height and maximum vertical jump touch height (McArdle et al., 2010). Once obtained, VJD from the Sargent jump-and-reach test can be entered into a predictive equation to compute peak power (PP), expressed in Watts (W) (Brooks et al, 2005; McArdle et al., 2010).

Since VJD can be used to calculate PP, this contributes to the effectiveness of the vertical jump test in evaluating anaerobic performance (Brooks et al, 2005; McArdle et al., 2010). While the Wingate Anerobic Test (WAnT) can also quantify PP, its use involves more elaborate procedures and responsibilities on behalf of both the participant and the investigator, in comparison to the vertical jump test (Duquette et al., 2024; Zupan et al., 2009). For example,

Author's address Olivia N. Morassutti, Department of Kinesiology, University of Windsor, 401 Sunset Avenue, Windsor, Canada
morassuo@uwindsor.com

the vertical jump test is quick and easy to conduct, requires minimal and inexpensive equipment, and does not require the presence of extensively trained personnel to monitor test completion (Ramírez-Vélez et al., 2017). Moreover, it is more practical for the vertical jump test to be performed by a wide range of populations with varying athletic abilities (Ramírez-Vélez et al., 2017). This test is also non-exhausting and less strenuous than the WAnT, therefore, minimizing the health and safety risks for participants (Ramírez-Vélez et al., 2017). The use of the Sargent jump-and-reach test is bolstered by the fact that it is a reliable and valid research tool (de Salles et al., 2012; Markovic et al., 2004). While there are numerous advantages to utilizing the vertical jump test to assess anaerobic power, its evaluative capacity is limited by the paucity of established normative-reference standards in the literature based on large participant cohorts. Therefore, the development of a set of norms would be especially valuable for evaluating various participant groups (e.g., athletic and general/non-athletic populations). Athletes, especially individuals who participate in sports that require proficiency in anaerobic power (e.g., volleyball, basketball, ice hockey, etc.), may utilize norms to identify baseline performance or to track improvements throughout the completion of a training program. In contrast, normative-reference values can be employed by general, non-athletic populations, as they can act as a reference for comparison to assess health status (especially since the test is easy to conduct). This may, in fact, serve to motivate individuals to work toward achieving improved levels of physical fitness and anaerobic capacity, thus potentially leading to the amelioration of their overall health and functioning.

Several studies have examined the use of the vertical jump test as a tool to ultimately assess vertical jumping power (Bovet et al., 2007; Çakir-Atabek, 2014; Changela & Bhatt, 2012; de Salles et al., 2012; Donskov et al., 2021; Gross & Lüthy, 2020; Holm et al., 2008; Kochanowicz et al., 2016; Markovic et al., 2004; Nikolaidis et al., 2016; Patterson & Peterson, 2004; Payne et al., 2000; Ramírez-Vélez et al., 2017; Sumnik et al., 2013; Taylor et al., 2010; Temfemo et al., 2008; Tounsi et al., 2014). Some studies specifically used the Sargent jump-and-reach test (de Salles et al., 2012; Markovic et al., 2004), whereas others implemented different variations of the vertical jump test (e.g., squat jump [Gross & Lüthy, 2020; Markovic et al., 2004; Nikolaidis et al., 2016; Temfemo et al., 2008; Tounsi et al., 2014] or single-leg jump [Donskov et al., 2021]), or used predictive equations (Çakir-Atabek, 2014; Gross & Lüthy, 2020; Patterson & Peterson, 2004; Ramírez-Vélez et al., 2017; Sumnik et al., 2013; Taylor et al., 2010; Tounsi et al., 2014) to determine vertical jumping power. Additionally, there has been a focus on appraising the validity and reliability of the Sargent jump-and-reach test (de Salles et al., 2012; Markovic et al., 2004). The majority of the literature has adopted a narrowed approach by analyzing vertical jumping power data and generating norms solely based on specific populations. For example, vertical jumping power has been reported among children, defined as individuals aged six to 15 years (Holm et al., 2008; Kochanowicz et al., 2016; Ramírez-Vélez et al., 2017; Taylor et al., 2010) and adolescents, defined as individuals aged 10 to 19 years (Bovet et al., 2007; Çakir-1, 2004; Changela & Bhatt, 2012; de Salles et al., 2012; Donskov et al., 2021; Nikolaidis et al., 2016; Sumnik et al., 2013; Temfemo et al., 2008; Tounsi et al., 2014). Furthermore, different high school (Changela & Bhatt, 2012), elite (Donskov et al., 2021), and professional (Gross & Lüthy, 2020) athletic populations have been assessed. Lastly, various nations' populations (e.g., Brazilian [de Salles et al., 2012], Colombian [Ramírez-Vélez et al., 2017], Czech [Sumnik et al., 2013], British [Taylor et al., 2010], Tunisian [Tounsi et al., 2014], etc.) have been a highlighted focus of study. Many of these studies have reported data regarding both absolute and relative vertical jumping power (Çakir-Atabek, 2014; Payne et al., 2000; Pennington, 2014; Ramírez-Vélez et al., 2017), as well as VJD (Bovet et al., 2007; Çakir-Atabek, 2014; Patterson & Peterson, 2004; Payne et al., 2000; Ramírez-Vélez et al., 2017; Sumnik et al., 2013; Taylor et al., 2010; Tounsi et al., 2014). While some studies have published percentile rankings (Bovet et al., 2007; Patterson & Peterson, 2004; Payne et al., 2000; Ramírez-Vélez et al., 2017; Sumnik et al., 2013; Taylor et al., 2010; Tounsi et al., 2014), very few performance classifications based on vertical jumping power data have been developed (Brooks et al., 2007). Additionally, few studies have been uniquely dedicated to establishing vertical jumping power normative-reference standards based on a large Canadian participant population (Payne et al., 2000).

Due to a narrowed focus on the aforementioned populations, the results of corresponding studies lack generalizability to individuals who are not representative of the studied populations. This, in turn, means that the normative-reference values that currently exist in the literature cannot be used for accurate comparison and analysis among the present Canadian adult population. Therefore, the current study aimed to develop peak vertical jumping power normative-reference standards, including percentile rankings and performance classifications, based on a large-scale, university-aged healthy Canadian population.

Materials and methods

A sample population of 960 participants volunteered to complete the Sargent jump-and-reach test with the ultimate goal of determining peak vertical jumping power. VJD, measured in inches and converted to metres (m), was quantified during testing, and subsequently used to determine absolute (W) and relative ($W \cdot kg^{-1}$) (PP). The dependent variables (i.e., absolute power, relative power, and VJD) were analyzed ($p < 0.05$) to assess for statistically significant differences between sexes and to allow for the development of normative-reference standards, percentile rankings, and performance classifications.

Participants

Participants were students enrolled in a human and exercise physiology laboratory-based course in the Department of Kinesiology at a Canadian university. A convenience sample was used since the inclusion criterion was course enrollment (n = 1042; 82 of which either declined participation [69], were excluded based on age [two – see below], had missing data [three], or a data entry error prevented the use of their data [eight]). Data collection occurred throughout nine semesters across a nine-year period (Fall 2010 to 2019). Following exclusions (described below in Statistical Analyses), 960 participants (422 males and 538 females) who ranged in age from 20 to 29 years participated in testing. The demographic characteristics (i.e., sex, age, body mass [BM], height, and body mass index [BMI]) of study participants are presented in Table 1.

Table 1. Demographic characteristics of study participants

Characteristics	Males (N = 422)	Females (N = 538)	Total (N = 960)
Age (years)	21.50	21.15	21.31
Body Mass (kg)	81.08 ± 13.46	64.82 ± 11.69	71.97 kg ± 14.88
Height (m)	1.79 ± 0.01	1.66 ± 0.01	1.71 ± 0.01
Body Mass Index (kg/m^2)	25.36 ± 3.46	23.71 ± 3.89	24.44 ± 3.80

*Abbreviations: N, sample size; kg, kilograms; m, metres.

This study's sample population encompassed participants with diverse athletic and fitness abilities (although this information was not quantified). Prior to testing, participants were required to complete the Get Active Questionnaire (Canadian Society for Exercise Physiology [CSEP], 2017) or a Physical Activity Readiness Questionnaire (to screen for the absence of contraindications to exercising) and sign institutionally cleared review board consent forms. Before performing the Sargent jump-and-reach test, it was imperative that participants conducted a proper warm-up to reduce injury risk, which involved activities such as running in-place, jumping jacks, and/or high knee jogging. The university's Research Ethics Board cleared this study. This study was conducted in compliance with the Declaration of Helsinki.

Protocol

The Sargent jump-and-reach test was conducted using a 1.27 m (50-inch) wall-mounted vertical jumping height scale (Canada), the bottom of which was positioned at a height of 1.91 m (75 inches) from the floor, marking the "zero line". Prior to testing, participants' BMs were obtained using the Physician Mechanical Balance Beam Scale (United States of America [USA], catalogue number: 654-450 KL).

All participants were required to follow the instructions provided in order to maximize safety while completing the Sargent jump-and-reach test (e.g., avoiding food consumption and smoking tobacco two hours prior to testing and refraining from caffeine and alcohol consumption and engaging in strenuous exercise six hours prior to testing).

As proper form and technique are essential when completing the Sargent jump-and-reach test, it was imperative for participants to carefully follow the test's outlined procedures. Specifically, participants were only allowed one movement down during the test. Any additional countermovements, such as swinging of the arms and/or hands could serve to improve performance and thus were not permitted. In order to calculate peak vertical jumping power, VJD (measured in inches) was first determined. VJD was defined as the value obtained when the standing reaching height (in inches) was subtracted from the vertical jumping reach height (in inches), as measured on the wall-mounted scale. To acquire standing reaching height, the participant stood with their dominant shoulder adjacent to the wall, while their shod feet were parallel, flat on the floor, and shoulder-width apart. Additionally, the participant's dominant arm reached as high as possible on the wall, with their arm and fingers fully extended, so that the palm of their hand was flat against the wall-mounted vertical jumping height scale. The highest point that the participant reached (typically the tip of their middle finger) was recorded by the investigator as their standing reaching height.

Next, to obtain vertical jumping reach height, the participant was instructed to assume a ready position, which required the adjustment of their feet into a comfortable jumping take-off stance, where they remained, without moving, prior to the vertical jump. To ensure that they were situated at an appropriate distance away from the wall, the participant placed their elbow on their hip to verify that there was minimal contact with the wall (i.e., their elbow was only allowed to brush against the wall). They then brought their arms downward and from backward to forward (one countermovement) while bending their knees into a semi-squat position. Following one rapid bend of the knees, the participant completed the vertical jump. This entailed moving their arms forward and upward while reaching and touching as high as possible on the wall-mounted vertical jumping height scale with their arm and fingers fully extended. The highest point touched by the participant was recorded. Participants were advised to land with their knees bent in order to absorb the forces created upon impact with the ground. Three jumps, each separated by a 10- to 15-second recovery period, were completed. The highest value recorded of the three jumps was used to determine VJD, which was subsequently used to calculate peak vertical jumping power.

Since the wall-mounted vertical jumping height scale utilized inches as the unit of measurement, VJD was converted from inches to centimetres (cm) prior to being entered into a predictive equation developed by Sayers et al. (1999) to determine (PP) ($PP[W] = 60.7 \cdot VJD[cm] + 45.3 \cdot BM[kg] - 2055$). Additionally, all variables that were measured (i.e., standing reaching height, vertical jumping reach height, and VJD) and calculated (i.e., PP) during testing were recorded by the investigator and saved for future analyses. The present study employed the Sayers Equation 2A (Sayers et al., 1999) to compute PP (in W) instead of the Lewis Equation (Fox & Mathews, 1974) ($power\ [kgm/s] = 2.21 \cdot BM[kg] \cdot \sqrt{VJD[m]}$), which has been found to possess several limitations (Harman et al., 1991). As reported by Harman et al. (1991), the Lewis Equation (Fox & Mathews, 1974) should no longer be used, as it was developed based on a small sample size, has never been peer-reviewed, and does not provide an accurate prediction of average power or PP. In fact, the Lewis Equation (Fox & Mathews, 1974) tends to underestimate PP by 70% in comparison to the Sayers Equation (Harman et al., 1991; Sayers et al., 1999).

Statistical Analyses

Before the main statistical analyses were performed, the collected data were meticulously examined for the presence of abnormalities. Any outliers identified in the raw data were included in the statistical analyses, as long as they were not considered to be erroneous due to human or data entry errors. Data were removed from the dataset for various reasons: data entry errors (eight), missing data (three), and age (two participants 40+ years of age, as they were not considered to be representative of the population being studied). This led to the generation of the study's final sample size ($n = 960$ individuals, 422 males and 538 females). Statistical analyses were completed using the International Business Machines Corporation (IBM) Statistical Package for the Social Sciences (SPSS) software (version 28) (USA). Mean and standard deviation (SD) values for absolute power, relative power, and VJD were generated in SPSS using frequencies and descriptive statistics. Absolute PP was provided in W, relative PP was expressed in $W \cdot kg^{-1}$, and VJD was provided in m. In order to compare the means of the dependent variables (i.e., absolute power, relative power, and VJD) and test for statistical significance ($p < 0.05$) between males and females, an independent samples t-test was run, and Cohen's d was used to determine effect size.

Vertical jumping power classifications were developed for both sexes based on absolute (W) and relative ($W \cdot kg^{-1}$) PP, as well as VJD (m). The first step required to construct the performance classifications was to compute the range and Z-scores for the raw absolute power, relative power, and VJD data. The ranges were then divided by seven to allow for the creation of seven classifications, each separated by equal raw data scores and SD intervals. The procedure used to construct performance classifications in the present study was identical to the method used by Duquette et al. (2024) and a modification to the method used by Zupan et al. (2009). Male absolute power (W) had a Z-score range of 8.36 (−3.13 to 5.23). As such, all seven performance classifications were separated by 1.19 SDs, which corresponded to equal raw data score categories of 1097 W (since the raw data score range of 7681 W was divided by seven). For example, 1097 W was subtracted from the largest raw PP score collected (9536 W – 1097 W) to produce an 'elite' classification of > 8439 W. Similarly, 1097 W was subtracted from 8439 W to produce an 'excellent' classification of 7342 W – 8439 W. The range of Z-scores for female absolute power (W) was 8.00 (−2.68 to 5.32), which resulted in each performance classification being separated by intervals of 1.14 SDs and corresponded to equal raw data score categories of 889 W (since the raw data score range of 6220 W was divided by seven). For example, 889 W was subtracted from the largest raw PP score collected (7109 W – 889 W) to produce an 'elite' classification of > 6220 W. Similarly, 889 W was subtracted from 6220 W to produce an 'excellent' classification of 5331 W – 6220 W. Following the procedure used by Duquette et al. (2024) that modified the work of Zupan et al. (2009), the performance classifications were labeled as 'elite', 'excellent', 'above average', 'average', 'below average', 'fair', and 'poor'. The same process was used to generate performance classifications for relative power and VJD.

Results

Results generated from the Sargent jump-and-reach test, presented in Table 2, encompass absolute (W) and relative ($W \cdot kg^{-1}$) PP and VJD (m) data. Statistical analysis using independent samples t-tests revealed statistically significant sex-based differences across all performance variables, with male participants exhibiting higher values in each metric assessed. Effect sizes indicated large differences between groups. The collected data were subsequently used to create seven sex-specific performance classifications, ranging from 'poor' to 'elite' (Tables 3 and 4). Additionally, percentile rankings for male and female absolute PP, relative PP, and VJD were created (Tables 5 and 6). These rankings were calculated in SPSS using descriptive and frequency analyses and were reported at five-percentile intervals from the fifth to 95th percentile.

Table 2. Vertical jumping power in young Canadian adults

Variable	Sex	N	Mean ± SD	Minimum – Maximum
Absolute Power (W)	Males	422	4831 ± 1046	1855–9536
	Females	538	3106 ± 841	889–7109
	Total	960	3864 ± 1269	889–9536
Relative Power ($W \cdot kg^{-1}$)	Males	422	59.90 ± 10.93	26.57–127.23
	Females	538	48.07 ± 10.82	16.39–130.73
	Total	960	53.27 ± 12.35	16.39–130.73
Vertical Jump Distance (m)	Males	422	0.53 ± 0.14	0.04–1.19
	Females	538	0.37 ± 0.11	0.06–1.05
	Total	960	0.44 ± 0.15	0.04–1.19

*Abbreviations: N, sample size; W, watts; $W \cdot kg^{-1}$, watts per kilogram; m, metres.

Table 3. Vertical jumping power classifications for males

Classifications	Absolute Power (W)	Relative Power ($W \cdot kg^{-1}$)	Vertical Jump Distance (m)
Elite	> 8439	> 112.85	> 1.03
Excellent	7342–8439	98.47–112.85	0.87–1.03
Above Average	6245–7341	84.09–98.46	0.71–0.86
Average	5148–6244	69.71–84.08	0.55–0.70
Below Average	4051–5147	55.33–69.70	0.39–0.54
Fair	2954–4050	40.95–55.32	0.23–0.38
Poor	< 2954	< 40.95	< 0.23

*Abbreviations: W, watts; $W \cdot kg^{-1}$, watts per kilogram; m, metres.
*Note: Classifications for absolute power (in W) were calculated by rounding to the closest whole number value, and classifications for relative power (in $W \cdot kg^{-1}$) and VJD (m) were calculated by rounding to the closest two decimal places.

Table 4. Vertical jumping power classifications for females

Classifications	Absolute Power (W)	Relative Power ($W \cdot kg^{-1}$)	Vertical Jump Distance (m)
Elite	> 6220	> 114.40	> 0.91
Excellent	5331–6220	98.07–114.40	0.77–0.91
Above Average	4442–5330	81.74–98.06	0.63–0.76
Average	3553–4441	65.41–81.73	0.49–0.62
Below Average	2664–3552	49.08–65.40	0.35–0.48
Fair	1775–2663	32.75–49.07	0.21–0.34
Poor	< 1775	< 32.75	< 0.21

*Abbreviations: W, watts; $W \cdot kg^{-1}$, watts per kilogram; m, metres.
*Note: Classifications for absolute power (in W) were calculated by rounding to the closest whole number value, and classifications for relative power (in $W \cdot kg^{-1}$) and VJD (m) were calculated by rounding to the closest two decimal places.

Table 5. Vertical jumping power percentile rankings for males

Percentiles	Absolute Power (W)	Relative Power ($W \cdot kg^{-1}$)	Vertical Jump Distance (m)
5	3127	40.81	0.28
10	3505	47.85	0.37
15	3854	51.10	0.41
20	4026	52.92	0.43
25	4171	54.35	0.46
30	4351	55.71	0.48
35	4470	56.36	0.49
40	4571	57.63	0.51
45	4674	58.56	0.52
50	4804	59.79	0.53
55	4891	61.06	0.55
60	5026	61.84	0.56
65	5165	62.61	0.57
70	5385	64.25	0.58
75	5502	65.61	0.60
80	5643	67.20	0.62
85	5831	68.68	0.64
90	6082	70.94	0.67
95	6424	75.28	0.75

*Abbreviations: W, watts; $W \cdot kg^{-1}$, watts per kilogram; m, metres.
*Note: Percentile rankings were calculated by rounding to the closest two decimal places.

Table 6. Vertical jumping power percentile rankings for females

Percentiles	Absolute Power (W)	Relative Power ($W \cdot kg^{-1}$)	Vertical Jump Distance (m)
5	1955	30.73	0.18
10	2236	38.61	0.26
15	2393	40.00	0.28
20	2513	41.46	0.30
25	2587	42.49	0.30
30	2680	43.26	0.32
35	2770	44.37	0.33
40	2842	45.08	0.34
45	2923	46.29	0.35
50	3006	47.18	0.36
55	3085	48.31	0.37
60	3179	49.42	0.38
65	3302	50.53	0.39
70	3397	51.62	0.41
75	3525	52.90	0.42
80	3641	54.18	0.43
85	3776	56.23	0.45
90	4024	58.52	0.47
95	4688	63.87	0.56

*Abbreviations: W, watts; $W \cdot kg^{-1}$, watts per kilogram; m, metres.
*Note: Percentile rankings were calculated by rounding to the closest two decimal places.

Discussion

This study aimed to develop sex- and age-specific peak vertical jumping power and VJD normative-reference standards, including percentile rankings and performance classifications, that are representative of a healthy Canadian young adult population. Male participants produced greater absolute PP, relative PP, and VJD values in comparison to female participants. These results support common absolute (Çakir-Atabek, 2014; Gross & Lüthy, 2020; Patterson & Peterson, 2004; Ramírez-Vélez et al., 2017; Sumnik et al., 2013; Taylor et al., 2010) and relative (Gross & Lüthy, 2020; Sumnik et al., 2013; Taylor et al., 2010) power and VJD (Çakir-Atabek, 2014; Patterson & Peterson, 2004; Payne et al., 2000; Ramírez-Vélez et al., 2017; Taylor et al., 2010; Tounsi et al., 2014) findings in the literature.

To allow for comparison between study results, Table 7 highlights the absolute power (W), relative power ($W \cdot kg^{-1}$), and VJD (m) values from the Canadian male population, as well as the data from other published studies that have assessed vertical jumping power among male participants. The absolute and relative PP values obtained for the Canadian male adult population were 4831±1046 W and 59.90± 10.93 $W \cdot kg^{-1}$, respectively. This absolute PP value was greater than those reported by Ramírez-Vélez et al. (2017) (2986 ± 659 W) and Taylor et al. (2010) (3242 ± 584 W), who also used the Sayers Equation 2A (Sayers et al., 1999) to compute vertical jumping power. This finding can potentially be explained by the fact that the Canadian population was older, and they also may have had a higher degree of physical fitness. This notion is plausible given that the present study's participants were enrolled in a Kinesiology undergraduate degree, which may have contributed to a more profound knowledge and understanding of the human body and overall health, leading to an increased motivation and commitment to maintain physical fitness, and therefore a superior vertical jump testing performance. However, it is important to note that only a small proportion of the participants in the present study were athletes, so it could be argued that the sampled Canadian adult population was indeed representative of the general populace. The present study's mean VJD was also higher than the values found in several studies (Çakir-Atabek, 2014; Ramírez-Vélez, et al., 2017; Sumnik et al., 2013; Tounsi et al., 2014), which ranged from 0.29 ± 0.05 m to 0.38 ± 0.07 m. These studies included participants who were younger in age (16 to 19 years) and who originated from other countries (e.g., Tunisia, Colombia, etc.), which could account for the lower VJD values. In contrast, the mean VJD for the Canadian male cohort (0.53 ± 0.14 m) was similar to the results reported by Patterson and Peterson (2004) (0.56 ± 0.09 m) and Payne et al. (2000) (0.50 ± 0.01 m), which can likely be attributed to the demographic similarities of these participant populations (e.g., age, health status, geographical location, etc.).

Table 7. Comparison of reported male vertical jumping power values

Study	Mean age or age group (in years)	Sample size	Equation used	Absolute power (W)	Relative power ($W \cdot kg^{-1}$)	Vertical jump distance (m)
Present study	20–29	422	Sayers et al.**	4831 ± 1046	59.90 ± 10.93	0.53 ± 0.14
Çakir-Atabek (2014)	16	13	Lewis et al.	831 ± 217	N/A	0.36 ± 0.05
Gross and Lüthy (2020)	18–31	13	Regression	5262 ± 820	62.00 ± 6.00	N/A
Patterson and Peterson (2004)	21–30	500	Sayers et al.***	4855 ± 711	N/A	0.56 ± 0.09
Payne et al. (2000)	20–29	73	N/A	N/A	N/A	0.50 ± 0.01
Ramírez-Vélez et al. (2017)	17–17.9	241	Sayers et al.**	2986 ± 887	N/A	0.38 ± 0.07
Sumnik et al. (2013)	18	N/A	Regression	4055 ± 707	57.10 ± 5.30	N/A
Taylor et al. (2010)	15	106	Sayers et al.**	3242 ± 584	N/A	0.37 ± 0.06
Tounsi et al. (2014)	19	37	Regression	N/A	14.39 ± 1.45	0.29 ± 0.05

*Abbreviations: W, watts; $W \cdot kg^{-1}$, watts per kilogram; m, metres; N/A, not available.
** Sayers et al. (1999) Equation 2A: Peak power (W) = 60.7 × vertical jump distance (cm) + 45.3 × body mass (kg) – 2055
*** Sayers et al. (1999) Equation 2B: Peak power (W) = 51.9 × countermovement jump (cm) + 48.9 × body mass (kg) – 2007

Direct comparisons were not always possible, as some studies utilized different predictive equations to determine PP instead of the Sayers Equation 2A (Sayers et al., 1999), which was employed in the present study. For example, Çakir-Atabek (2014) used the Lewis Equation (Fox & Mathews, 1974) to obtain the absolute power values (831 ± 217 W) for their male participant population. This is especially noteworthy as it has been suggested that the Lewis Equation (Fox & Mathews, 1974) tends to underestimate predicted PP by approximately 70% in comparison to the Sayers Equation (Harman et al., 1991; Sayers et al., 1999). Therefore, this notion could account for the difference in the male absolute PP data reported by Çakir-Atabek (2014) in comparison to the present study. Additional studies (Gross & Lüthy, 2020; Sumnik et al., 2013; Tounsi et al., 2014) developed their own regression equations and reported absolute and relative power values ranging from 4055 ± 707 W to 5262 ± 820 W and 14.39 ± 1.45 $W \cdot kg^{-1}$ to 62.00 ± 6.00 $W \cdot kg^{-1}$, respectively. Lastly, Patterson and Peterson (2004) computed absolute power using the Sayers Equation 2B (PP[W] = 51.9 · VJD[cm] + 48.9 · BM[kg] – 2007) (Sayers et al., 1999) and reported similar findings (4855 ± 711 W) to the present study.

For comparison purposes, available female data, including absolute power (W), relative power ($W \cdot kg^{-1}$), and VJD (m), acquired from both the present study and the current literature, are reported in Table 8. It is important to note that the findings that were observed through the assessment of female participants' data can be explained using the same rationale that justified the findings reported among the male participants. The Canadian female participants had a mean absolute and relative PP measuring 3106 ± 841 W and 48.07 ± 10.82 $W \cdot kg^{-1}$, respectively. The sampled Canadian female adult population's mean absolute PP was greater than the female data reported by Ramírez-Vélez et al. (2017) (2115 ± 542 W) and Taylor et al. (2010) (2261 ± 517 W). Additional studies in the literature used different equations to calculate vertical jumping power. For example, Çakir-Atabek (2014) used the Lewis Equation (Fox & Mathews, 1974) and Patterson and Peterson (2004) used the Sayers Equation 2B (Sayers et al., 1999), while other studies developed their own regression equations (Gross & Lüthy, 2020; Sumnik et al., 2013; Tounsi et al., 2014) to determine absolute power (ranging from 572 ± 50 W to 3014 ± 554 W) and relative power (ranging from 9.82 ± 1.20 W·kg^{-1} to 47.00 ± 7.00 W·kg^{-1}). The present study's mean VJD (0.37 ± 0.11 m) was greater than the VJD data reported by Çakir-Atabek (2014), Payne et al. (2000), Ramírez-Vélez et al. (2017), Taylor et al. (2010) and Tounsi et al. (2014), which ranged from 0.15 ± 0.3 m to 0.30 ± 0.01 m, and was similar to the findings observed by Patterson and Peterson (2004) (0.36 ± 0.06 m).

Table 8. Comparison of reported female vertical jumping power values

Study	Mean age or age group (in years)	Sample size	Equation used	Absolute power (W)	Relative power (W·kg^{-1})	Vertical jump distance (m)
Present Study	20–29	538	Sayers et al.**	3106 ± 841	48.07 ± 10.82	0.37 ± 0.11
Çakir-Atabek (2014)	16	11	Lewis et al.	572 ± 50	N/A	0.28 ± 0.04
Gross and Lüthy (2020)	18–31	7	Regression	3014 ± 554	47.00 ± 7.00	N/A
Patterson and Peterson (2004)	21–30	224	Sayers et al.***	2953 ± 641	N/A	0.36 ± 0.06
Payne et al. (2000)	20–29	83	N/A	N/A	N/A	0.30 ± 0.01
Ramírez-Vélez et al. (2017)	17–17.9	287	Sayers et al.**	2115 ± 542	N/A	0.28 ± 0.06
Sumnik et al. (2013)	18	N/A	Regression	2557 ± 424	44.50 ± 6.20	N/A
Taylor et al. (2010)	15	79	Sayers et al.**	2261 ± 517	N/A	0.29 ± 0.07
Tounsi et al. (2014)	19	45	Regression	N/A	9.82 ± 1.20	0.15 ± 0.03

*Abbreviations: W, watts; W·kg^{-1}, watts per kilogram; m, metres; N/A, not available.
** Sayers et al. (1999) Equation 2A: Peak power (W) = 60.7 × vertical jump distance (cm) + 45.3 × body mass (kg) – 2055
*** Sayers et al. (1999) Equation 2B: Peak power (W) = 51.9 × countermovement jump (cm) + 48.9 × body mass (kg) – 2007

The present study highlights the differences in data that exist in comparison to studies that have examined various national (Ramírez-Vélez et al., 2017; Takken et al., 2003; Temfemo et al., 2008) and athletic (Çakir-Atabek, 2014; Gross & Lüthy, 2020) populations, have smaller participant sample sizes (Çakir-Atabek, 2014; Gross & Lüthy, 2020; Payne et al., 2000; Taylor et al., 2010; Tounsi et al., 2014), and have implemented different predictive equations (Çakir-Atabek, 2014; Gross & Lüthy, 2020; Patterson & Peterson, 2004; Ramírez-Vélez et al., 2017; Sumnik et al., 2013; Taylor et al., 2010; Tounsi et al., 2014). The limitations exhibited in the aforementioned studies presented challenges when generalizing their results to a more comprehensive population that encompassed a broader range of athletic abilities, similar to the Canadian population assessed in the present study. As such, to support practical applications and ensure accuracy when comparing and analyzing absolute and relative PP and VJD in the context of vertical jump testing, developing normative-reference values for young and healthy Canadian adults is necessary.

While numerous studies have developed percentile classifications for both sexes based on vertical jump test PP data (Bovet et al., 2007; Patterson & Peterson, 2004; Payne et al., 2000; Ramírez-Vélez et al., 2017; Sumnik et al., 2013; Taylor et al., 2010; Tounsi et al., 2014), very few are known to have established performance classifications (Brooks et al., 2005). In contrast to the present study's seven performance classifications, the *Canadian Physical Activity, Fitness and Lifestyle Appraisal (CPAFLA): CSEP's Plan for Healthy Active Living's* findings, as published by Brooks et al. (2005), constructed five age group- and sex-specific classifications for absolute power (in kgm/s) only, using the Lewis Equation (Fox & Mathews, 1974). These performance classifications were converted to W for ease of comparison. They were labelled as 'excellent', 'very good', 'good', 'fair', and 'needs improvement'. The absolute power values needed to achieve the highest performance classification ('excellent') for 20- to 29-year-olds in the CPAFLA (Brooks et al., 2005) were > 1187 W for males and > 765 W for females. Additionally, the lowest classification ('needs improvement') for males and females was < 716 W and < 500 W, respectively (Brooks et al., 2005). The present study constructed performance classifications for absolute PP, relative PP, and VJD data. Based on the Canadian adult population's absolute PP data, the highest classification ('elite') for males and females had corresponding values of > 8439 W and > 6220 W, respectively, while the lowest performance classification ('poor') was designated to be < 2954 W for males and < 1775 W for females. Performance classifications were also established for relative PP ('elite': > 112.85 W·kg^{-1} for males and > 114.40 W·kg^{-1} for females; 'poor': < 40.95 W·kg^{-1} for males and < 32.75 W·kg^{-1} for females) and VJD ('elite': > 1.03 m for males and > 0.91 m for females; 'poor':

< 0.23 m for males and < 0.21 m for females). The current study lays the foundation for establishing performance classifications due to the discrepancies that exist in comparison to the CPAFLA (Brooks et al., 2005) data, in addition to the current lack of relative power and VJD classifications in the literature.

Percentile rankings generated based on the data from the present Canadian adult population identified the 50th percentile for absolute PP as being 4804 W for male participants and 3006 W for female participants. Greater values for male participants in comparison to female participants were observed for all percentile rankings. Both sexes had higher 50th percentile rankings for absolute PP compared to the male and female data reported by Ramírez-Vélez et al. (2017) (3062 W and 2036 W, respectively) and Taylor et al. (2010) (3185 W and 2223 W, respectively). Moreover, the present study's 50th percentile rankings for relative PP (males: 59.79 $W \cdot kg^{-1}$, females: 47.18 $W \cdot kg^{-1}$) were greater than the data reported by Sumnik et al. (2013) (males: 54.20 $W \cdot kg^{-1}$, females: 43.50 $W \cdot kg^{-1}$) and Tounsi et al. (2014) (males: 14.4 $W \cdot kg^{-1}$, females: 9.83 $W \cdot kg^{-1}$). The Canadian male adult population's 50th percentile VJD value was 0.53 m. This percentile score was higher than the values reported by several studies (Ramírez-Vélez et al., 2017; Taylor et al., 2010; Tounsi et al., 2014), which were 0.38 m, 0.37 m, and 0.29 m, respectively. In contrast, the present study's male 50th percentile score was similar to the data reported by Patterson and Peterson (2004) (0.57 m), Payne et al. (2000) (0.50 m), and Sumnik et al. (2013) (0.52 m). Among female participants, the present study reported a 50th percentile VJD score of 0.36 m, which was higher than the values reported by Tounsi et al. (2014), Ramírez-Vélez et al. (2017), and Taylor et al. (2010) (range of 0.15 m to 0.28 m) and similar to the percentile scores observed in other studies (Patterson & Peterson, 2004; Payne et al., 2000; Sumnik et al., 2013), which ranged from 0.30 to 0.40 m.

Future studies should aim to establish a standardized protocol (e.g., type of vertical jump performed, predictive equation used, etc.) to allow for the accurate comparison and evaluation of vertical jumping power normative-reference values developed through the implementation of the vertical jump test. This is especially important, as some predictive equations (i.e., the Lewis Equation [Fox & Mathews, 1974]) possess notable limitations in predicting PP in comparison to others (i.e., the Sayers Equation) (Harman et al., 1991; Sayers et al., 1999). Additionally, further examining the use of the Sayers Equation 2A (Sayers et al., 1999), specifically in the context of vertical jumping power data located at the far extremes of the study's population (i.e., 'elite' performance classification), given the large magnitude of the reported values (i.e., > 8439 W for males and > 6220 W for females), may be of interest. It is important to acknowledge that differences in methodology and measurement (e.g., techniques used to execute the movement during the vertical jump test, etc.) can influence testing data and also yield varying results between studies (Gajewski et al., 2018; Xu et al., 2023). For example, Gajewski et al. (2018) determined that countermovement depth serves to explain the relationship between maximum power and vertical jump height. As such, conducting a future study to control for countermovement depth in order to determine its impact on vertical jumping power values would be of interest. Although the present study begins to fill a gap with respect to Canadian adult data based on a large cohort of participants, conducting additional studies in different Canadian regions would be favourable, as they could provide confirming evidence of the normative-reference values and performance classifications developed in the present study. Furthermore, focusing on constructing normative-reference standards based on specific populations (e.g., individuals from different countries, athletes, non-athletes, different age groups and BMs, etc.) to determine if there exist similar trends to those exhibited in the present study would be of benefit and would further supplement the literature, potentially leading to the development of global norms. Future research should also focus on determining whether a correlation between the anaerobic power developed during the vertical jump test and the WAnT exists. Should there be a strong correlation between the PP produced during both tests, this could provide an alternative, more efficient method to quantify anaerobic power and could further validate the use of the vertical jump test. This would, in turn, be less strenuous and exhausting for participants, thus, minimizing the inherent health and safety risks that are associated with the WAnT.

Conclusion

The main focus of this study was to establish vertical jumping power normative values, including percentile rankings and performance classifications, based on a large-scale population of Canadian university students. Conducting the vertical jump test can facilitate the acquisition of valuable data that can subsequently allow for the quantification of peak vertical jumping power, thus providing insight into an individual's performance in various fitness and exercise tasks. The development of normative tables, percentile rankings, and performance classifications is essential for athletes and non-athletes alike, particularly for comparison when evaluating baseline performance and tracking improvements over time, as well as assessing health status and functioning. The fact that a wall-mounted vertical jump test can be conveniently conducted by participants of varying athletic abilities quickly and with ease, requires minimal and low-cost equipment, and does not require trained personnel to complete, lends to the practicality of its utilization, especially in comparison to evaluation using a force platform or the WAnT.

Conflict of interest: Author state no conflict of interest

References

1. Bovet, P., Auguste, R., & Burdette, H. (2007). Strong inverse association between physical fitness and overweight in adolescents: A large school-based survey. *International Journal of Behavioral Nutrition and Physical Activity*, *4*(24), 1–8. https://doi.org/10.1186/1479-5868-4-24
2. Brooks, G. A., Fahey, T. D., & Baldwin, K. M. (2005). Exercise physiology: Human bioenergetics and its applications (4th ed.). New York, NY: McGraw Hill.
3. Canadian Society for Exercise Physiology (CSEP). (2017). *CSEP Get Active Questionnaire*. https://csep.ca/2021/01/20/pre-screening-for-physical-activity/#
4. Çakir-Atabek, H. (2014). Relationship between anaerobic power, vertical jump and aerobic performance in adolescent track and field athletes. *Journal of Physical Education and Sport*, *14*(4), 643–648. https://doi.org/10.7752/jpes.2014.04100
5. Changela, P. K., & Bhatt, S. (2012). The correlational study of the vertical jump test and Wingate cycle test as a method to assess anaerobic power in high school basketball players. *International Journal of Scientific Research*, *2*(6), 1–6.
6. de Salles, P., Vasconcellos, F., de Salles, G., Fonseca, R., & Dantas, E. (2012). Validity and reproducibility of the Sargent jump test in the assessment of explosive strength in soccer players. *Journal of Human Kinetics*, 33, 115–121. https://doi.org/10.2478/v10078-012-0050-4
7. Donskov, A. S., Brooks, J. S., & Dickey, J. P. (2021). Normative reference of the single leg, medial countermovement jump in adolescent youth ice hockey players. *Sports*, *9*(8), 105–113. https://doi.org/10.3390/sports9080105
8. Duquette, A., Morassutti, O., Gyemi, L., & van Wyk, P. (2024). Wingate normative-reference values for a large cohort of Canadian university students. *Biomedical Human Kinetics*, *16*(1), 78–88. https://doi.org/10.2478/bhk-2024-0008
9. Fox, E. L., & Mathews, D. K. (1974). Interval training: Conditioning for sports and general fitness. Saunders. https://doi.org/10.1093/ptj/54.12.1351
10. Gajewski, J., Michalski, R., Buśko, K., Mazur-Różycka, J., & Staniak, Z. (2018). Countermovement depth – A variable which clarifies the relationship between maximum power output and height of a vertical jump. *Acta of Bioengineering and Biomechanics*, *20*(1), 127–134.
11. Gross, M., & Lüthy, F. (2020). Anaerobic power assessment in athletes: Are cycling and vertical jump tests interchangeable? *Sports*, *8*(5), 60–74. https://doi.org/10.3390/sports8050060
12. Harman, E. A., Rosenstein, M. T., Frykman, P. N., Rosenstein, R. M., & Kraemer, W. J. (1991). Estimation of human power output from vertical jump. *Journal of Strength & Conditioning Research*, *5*(3), 116–120. https://doi.org/10.1519/00124278-199108000-00002
13. Holm, I., Fredriksen, P.M., Fosdahl, M., & Vøllestad, N. (2008). A normative sample of isotonic and isokinetic muscle strength measurements in children 7 to 12 years of age. *Acta Paediatrica*, *97*(5), 602–607. https://doi.org/10.1111/j.1651-2227.2008.00709.x
14. Kochanowicz, A., Niespodzinski, B., Mieszkowski, J., Kochanowicz, K., & Zasada, M. (2016). Vertical jump peak power estimation in young male gymnasts. *Baltic Journal of Health and Physical Activity*, *8*(1), 25–31. https://doi.org/10.29359/BJHPA.08.1.03
15. Lelieveld, O. T., van Brussel, M., Takken, T., van Weert, E., van Leeuwen, M. A., & Armbrust, W. (2007). Aerobic and anaerobic exercise capacity in adolescents with juvenile idiopathic arthritis. *Arthritis & Rheumatism*, *57*(6), 898–904. https://doi.org/10.1002/art.22897
16. Markovic, G., Dizdar, D., Jukic, I., & Cardinale, M. (2004). Reliability and factorial validity of squat and countermovement jump tests. *Journal of Strength & Conditioning Research*, *18*(3), 551–555. https://doi.org/10.1519/1533-4287(2004)18%3C551:RAFVOS%3E2.0.CO;2
17. McArdle, W. D., Katch, F. I., & Katch, V. L. (2010). Exercise physiology: Nutrition, energy, and human performance (7th ed.). Philadelphia, PA: Lippincott, Williams, & Wilkins.
18. Nikolaidis, P. T., Afonso, J., Clemente-Suarez, V. J., Alvarado, J. R. P., Driss, T., Knechtle, B., & Torres-Luque, G. (2016). Vertical jumping tests versus Wingate anaerobic test in female volleyball players: The role of age. *Sports*, *4*(1), 9–16. https://doi.org/10.3390/sports4010009
19. Patterson, D., & Peterson, D. F. (2004). Vertical jump and leg power norms for young adults. *Measurement in Physical Education and Exercise Science*, *8*(1), 33–41. https://doi.org/10.1207/s15327841mpee0801_3
20. Payne, N., Gledhill, N., Katzmarzyk, P. T., Jamnik, V. K., & Keir, P. J. (2000). Canadian musculoskeletal fitness norms. *Canadian Journal of Applied Physiology*, *25*(6), 430–442. https://doi.org/10.1139/h00-028
21. Pennington, C. (2014). Determining the anaerobic power output differences between the genders in untrained adults. *American International Journal of Contemporary Research*, *4*(4), 64–77.
22. Ramírez-Vélez, R., Correa-Bautista, J. E., Lobelo, F., Cadore, E. L., Alonso-Martinez, A. M., & Izquierdo, M. (2017). Vertical jump and leg power normative data for Colombian school children aged 9-17.9 years: The FUPRECOL study. *Journal of Strength & Conditioning Research*, *31*(4), 990–998. https://doi.org/10.1519/JSC.0000000000001550
23. Sayers, S. P., Harackiewicz, D. V., Harman, E. A., Frykman, P. N., & Rosenstein, M. T. (1999). Cross-validation of three jump power equations. *Medicine & Science in Sports & Exercise*, *31*(4), 572–577. https://doi.org/10.1097/00005768-199904000-00013

24. Sumnik, Z., Matyskova, J., Hlavka, Z., Durdilova, L., Soucek, O., & Zemkova, D. (2013). Reference data for jumping mechanography in healthy children and adolescents aged 6-18 years. *Journal of Musculoskeletal and Neuronal Interactions*, *13*(3), 297–311.
25. Takken, T., van der Net, J., & Helders, P. J. M. (2003). Relationship between functional ability and physical fitness in juvenile idiopathic arthritis patients. *Scandinavian Journal of Rheumatology*, *32*(3), 174–178. https://doi.org/10.1080/03009740310002524
26. Taylor, M. J., Cohen, D., Voss, C., & Sandercock, G. R. (2010). Vertical jumping and leg power normative data for English school children aged 10-15 years. *Journal of Sports Sciences*, *28*(8), 867–872. https://doi.org/10.1080/02640411003770212
27. Temfemo, A., Hugues, J., Chardon, K., Mandengue, S.-H., & Ahmaidi, S. (2008). Relationship between vertical jumping performance and anthropometric characteristics during growth in boys and girls. *European Journal of Pediatrics*, *168*(4), 457–464. https://doi.org/10.1007/s00431-008-0771-5
28. Tounsi, M., Aouichaoui, C., Elloumi, M., Dogui, M., Tabka, Z., & Trabelsi, Y. (2014). Reference values of vertical jumping performances in healthy Tunisian adolescent. *Ann. Hum. Biol.*, *42*(2), 117–125. https://doi.org/10.3109/03014460.2014.926989
29. Xu, J., Turner, A., Comfort, P., Harry, J. R., McMahon, J. J., Chavda, S., & Bishop, C. (2023). A systematic review of the different calculation methods for measuring jump height during the countermovement and drop jump tests. *Sports Medicine*, *53*(5), 1055–1072. https://doi.org/10.1007/s40279-023-01828-x
30. Zupan, M. F., Arata, A. W., Dawson, L. H., Wile, A. L., Payn, T. L., & Hannon, M. E. (2009). Wingate anaerobic test peak power and anaerobic capacity classifications for men and women intercollegiate athletes. *Journal of Strength & Conditioning Research*, *2*(9), 2598–2604. https://doi.org/10.1519/JSC.0b013e3181b1b21b

Received 17.11.2024
Accepted 31.03.2025