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PHYSICAL CHARACTERISTICS AS INDICATORS OF PERFORMANCE IN YOUNG ALPINE SKIERS IN SUPER-G

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ABSTRACT

***Purpose**: The aim of this study is to determine the relationship between physical characteristics and performance in young alpine skiers in the Super-G discipline.*

***Methods**: A sample of 42 U16 alpine skiing competitors (23 boys and 19 girls) aged 14-15 years participated in the study. The physical characteristics were measured using the Inbody 720 Body Composition Analysis and 3D Body Scan devices. Performance data was obtained from official records of the Ski Association of Slovenia for the 2018/19 U16 competitive season. Variables such as body height, body weight, thigh circumference, waist circumference, chest circumference, shoulder circumference, muscle mass percentage, fat mass percentage, body mass index, and body fat percentage were analyzed. Pearson correlation coefficients and multiple regression analysis were used to assess the relationship between the physical characteristics and Super-G performance.*

***Results**: Significant correlations were found between body weight, thigh circumference, chest circumference, muscle mass percentage, and Super-G performance in boys. For girls, waist circumference, chest circumference, and body fat percentage were significantly correlated with performance. The multiple regression model explained 73% of the variance in the boys' performance and 59% in the girls', although the model itself was not statistically significant for predicting performance.*

***Conclusion**: Physical characteristics, especially muscle mass percentage and body circumferences, are significantly associated with Super-G performance in young alpine*

skiers. These findings underscore the importance of tailored training programs that consider individual physical characteristics to optimize competitive success in alpine skiing.

***Keywords**: alpine skiing, Super-G, physical characteristics, young athletes, body composition, performance indicators.*

TELESNE ZNAČILNOSTI KOT KAZALNIK USPEŠNOSTI MLADIH ALPSKIH SMUČARJEV V SUPERVELESLALOMU

IZVLEČEK

***Namen**: Namen raziskave je ugotoviti povezanost med telesnimi značilnostmi in uspešnostjo mladih alpskih smučarjev v superveleslalomu.*

***Metode**: V raziskavi je sodelovalo 42 tekmovalcev v alpskem smučanju kategorije U16 (23 dečkov, 19 deklic) v starosti 14–15 let. Telesne značilnosti so bile izmerjene z napravama Inbody 720 za analizo telesne sestave in 3D telesnim skeniranjem. Podatki o uspešnosti so bili pridobljeni iz uradnih zapisov Smučarske zveze Slovenije za tekmovalno sezono 2018/19 v kategoriji U16. Analizirane spremenljivke so vključevale telesno višino, telesno težo, obseg stegen, obseg pasu, obseg prsnega koša, obseg ramen, delež mišične mase, delež maščobne mase, indeks telesne mase in odstotek maščobe v telesu. Za oceno povezave med telesnimi značilnostmi in uspešnostjo v superveleslalomu smo uporabili Pearsonove korelacijske koeficiente in multiplo regresijsko analizo.*

***Rezultati**: Pri dečkih so bile ugotovljene pomembne povezave med telesno težo, obsegom stegen, obsegom prsnega koša, deležem mišične mase in uspešnostjo v superveleslalomu. Pri deklicah so bile pomembne povezave med obsegom pasu, obsegom prsnega koša in deležem telesne maščobe. Model multiple regresije je pojasnil 73 % variance z uspešnostjo pri dečkih in 59 % pri deklicah, čeprav model sam po sebi ni bil statistično pomemben za napovedovanje uspešnosti.*

***Zaključek**: Telesne značilnosti, zlasti delež mišične mase in telesni obsegi, so pomembno povezane z uspešnostjo v superveleslalomu pri mladih alpskih smučarjih. Ti izsledki poudarjajo pomembnost prilagojenih vadbenih programov, ki upoštevajo posamezne telesne značilnosti za optimizacijo tekmovalnega uspeha v alpskem smučanju.*

***Ključne besede**: alpsko smučanje, superveleslalom, telesne značilnosti, mladi športniki, telesna sestava, kazalniki uspešnosti.*

INTRODUCTION

Success in alpine skiing is influenced by numerous factors, including motor skills, physical characteristics, psychological traits, and technical abilities (Ferland & Comtois, 2018; McKnight, 2018; Müller, Schwameder, Kornexl, & Raschner, 1997; Puhalj, Lešnik, Povhe, Kelc, & Matejek, 2021). Among these, physical characteristics significantly impact skier performance. However, few studies have examined the relationship between physical characteristics and competitive performance using highly accurate measurement instruments, particularly in speed disciplines.

Rajtmajer (1984) identified a correlation between manifest and latent motor skills and anthropometric characteristics in young alpine skiers. Based on this research, he defined the type of elite alpine skier, which differs from the athletic type, with narrower shoulders, wider hips, longer upper limbs, shorter stature, and pronounced distal trunk and lower limb mass, particularly thigh muscle mass. Voluminous body mass is crucial in alpine skiing as competitors have to manage their body mass, which is paramount for competitive success (Lešnik, 1999). Klika and Malina (2003) found minor differences in the physical characteristics between successful and less successful skiers aged 14-18, noting better motor skills in the successful competitors. They also observed that combining physical characteristics, motor skills, and age predicts competitive success more effectively than physical characteristics or motor skills alone. They suggested including the skiing technique as a variable in future research. Scherr et al. (2011) noted that skiers with a higher muscle mass percentage were more successful in alpine skiing. Bandalo and Lešnik (2012) found that body constitution significantly influences skiing performance, with skiers having greater body mass and height and longer and broader lower limbs achieving better results. Critical parameters like height, weight, muscle mass percentage, and fat percentage affect a skier's ability to manage the speed and technical skiing demands (Bandalo & Lešnik, 2011). Skiers with more muscle mass generate better force, which is crucial for jumping and turn control. Body composition, especially body mass, predicts factors related to force and power in young alpine skiers (Bertozzi et al., 2024). Fat percentage influences aerodynamics and endurance, while taller skiers can utilize their height for better force transfer to the skis, enabling more effective turns and excellent stability at high speeds (Bandalo & Lešnik, 2011). The influence of physical measurements on young alpine skiers' performance proved statistically significant, with height having the most critical impact, while the body fat percentage had no statistical significance for performance (Šteharnik, 2013). Bandalo (2016) reported that

increased subcutaneous fat is related to the success of younger competitors, emphasizing the importance of body mass and height, muscle mass percentage, and lower limb joint diameters, especially the knee. Puhalj (2018) found that boys with higher body fat percentages and total body mass achieved better results, attributing this to simpler course setups favoring heavier competitors. Pernuš (2018) similarly found a significant relationship between body and muscle mass and competitive success in boys, while no such correlation was observed in girls.

Research and practice indicate that body constitution significantly impacts alpine skiers' competitive success (Ferland & Comtois, 2018). Alpine skiing involves full-body physical activity, requiring body and equipment control. Body weight is crucial for achieving top results. Optimal body positioning on the skis and sliding speed depend on gravitational force, terrain slope, and opposing forces. Heavier competitors thus have an advantage, contingent on the fat-free to fat mass ratio as excess fat negatively affects body control. Therefore, other variables like lower limb circumference (thigh circumference) and joint diameters (ankle and knee) are also important. Appropriate physical measurements are essential for top results, alongside proper physical preparedness and skiing technique (Bandalo & Lešnik, 2011; Lešnik & Žvan, 2007; Sands et al., 2021; Supej, 2008).

Vermeulen et al. (2017) also studied morphological characteristics and alpine skiing performance and found that female speed event specialists had more relative fat mass than technical event specialists. Regardless of gender, technical event specialists were lighter, with less relative fat mass than speed event specialists. Moderate correlations were found between speed event performance and body weight, with a higher relative fat mass linked to female speed event success, while lower ectomorphy correlated with male speed event success.

Technical skills are also crucial for alpine skiing success, involving correct skiing technique, rapid adaptation to varying snow conditions, and executing complex maneuvers (Puhalj & Lešnik, 2018). Competitors must master various skiing techniques to effectively navigate different terrains and snow conditions. Technical preparation involves precise course analysis, training on varied terrains, and improving specific technical elements like turns, jumps, and gliding. Super-G, a speed event, incorporates giant slalom and downhill elements. Super-G requires a low center of gravity and ski guidance on the sliding surface, deriving from the downhill technique. Apart from slightly shorter skis compared to downhill skiing, the equipment for Super-G is similar due to the lower speeds and better maneuverability requirements (Lešnik & Žvan, 2007). Super-G is the most demanding discipline in the U16 category (ages 14-15),

gradually introducing elements of speed disciplines. The height difference between the start and finish of Super-G courses should be between 250 and 450 meters, with an average of 40 direction changes (Smučarska zveza Slovenije – Otroški program, 2019).

Understanding the relationship between physical characteristics and alpine skiing performance is crucial for developing top young skiers. Physical characteristics like body mass, height, muscle mass, and body circumferences significantly influence the skiers' ability to meet the technical and physical demands of skiing. Based on research data, coaches can better tailor the training processes to individual competitors' needs, leading to better results and reduced injury risk.

Many studies indicate that children who mature biologically faster have advantages in some sports due to more developed skeletal systems and higher skeletal age (Škof, 2016). Older boys with advanced biological development show better motor skills and strength than their peers, while girls who mature later perform better than early developers. Young alpine skiers' physical characteristics change with growth and development, particularly during puberty, impacting skiing performance. Increases in muscle mass, changes in body composition, and growth are factors to consider when planning training and preparation for competitions.

The study aimed to determine the relationship between physical characteristics and competitive performance in young alpine skiers in the U16 category in Super-G. We sought to assess the correlation of body mass and height, thigh circumference, waist circumference, chest circumference, body mass index, fat and muscle mass percentage, and all the measured body composition variables with Super-G performance. Based on previous research, we hypothesize a statistically significant relationship between body mass and height and the young alpine skiers' Super-G performance. We also hypothesize that Super-G success correlates with thigh circumference, waist circumference, chest circumference, fat and muscle mass percentage, body mass index, and body composition variables.

METHODS

Participant Sample

The sample included U16 alpine skiing competitors aged 14-15 years. The U16 category is the oldest in Slovenia's children's competitive alpine skiing program. All the study participants were registered competitors with the Ski Association of Slovenia, representing 19 ski clubs across four Slovenian ski regions. The sample consisted of 23 boys and 19 girls competing in Super-G. Parents and children were informed about the study protocol and agreed to participate.

Measurement Instruments

Measurements were conducted using the Inbody 720 Body Composition Analysis device (Inbody720, 2024), which provides precise whole-body composition analysis, including basal metabolism, muscle balance, and body fat percentage. The Inbody 720 employs direct segmental multi-frequency bioelectrical impedance analysis to measure the resistance of alternating electrical currents through different body segments. The 3D Body Scan device ([TC]2 National Science Foundation study of Harvard University, USA) ([TC]2, 2024) was used for comprehensive body scanning, providing the body circumferences, segment lengths, and joint diameters or body part measurements. Variables deemed influential on Super-G performance based on previous research were included.

Data Collection Procedure

Data collection occurred in September 2018 under controlled conditions at the Faculty of Sport in the kinesiology laboratory. Body composition variables were measured using the Inbody 720 and 3D Body Scan devices. Performance data in Super-G were obtained from the official records of the Ski Association of Slovenia for the 2018/19 U16 competitive season, which included four Super-G competitions. Points were awarded to the top 30 competitors in each race. The competitor who placed first received 100 points; second place earned 80 points; third place 60 points; fourth 50 points; fifth 45 points, sixth 40 points, seventh 36 points, eighth 32 points; ninth 29 points; tenth 26 points; eleventh 24 points, twelfth 22 points, thirteenth 20 points, fourteenth 18 points, fifteenth 16 points, and then one point less for each subsequent position, down to thirtieth

place, which earned 1 point. The criterion for competition success was the total sum of points a competitor received across all four U16 Super-G competitions.

Data Processing Procedures

Body composition and Super-G performance variables were processed using IBM SPSS 23.0. Arithmetic means and standard deviations were calculated, followed by normality distribution checks using the Shapiro-Wilk test. Pearson correlation coefficients determined the relationship between individual variables and Super-G performance. Multiple regression analysis assessed the relationship between selected variable sets and Super-G performance. Assumptions of linearity, the normal distribution of the dependent variable, homoscedasticity, and multicollinearity were verified before calculating the correlations.

RESULTS

Table 1 presents the basic statistics for body composition and Super-G performance in boys, showing the most considerable within-group differences in body weight, waist circumference, shoulder diameter, muscle mass percentage, body mass index, and Super-G points, as well as minor differences in body fat percentage.

Table 1: Descriptive statistics for boys

Variables	N	Mean	Min	Max	SD
Body height	23	170.05	153	179.8	7.32
Body weight	23	60.07	39.5	79.8	10.99
Thigh circumference	23	55.47	46.3	68.3	6.57
Waist circumference	23	75.83	64.2	87.6	6.67
Chest circumference	23	89.73	78.7	102.5	6.99
Shoulder circumference	23	93.99	80.8	132.4	11.03
Muscle mass percentage	23	29.94	18.64	41.14	5.48
Fat mass percentage	23	6.56	2.3	16.2	3.54
Body mass index	23	20.86	16.65	26.49	2.68
Body fat percentage	23	9.46	7	10.8	1.03
Super-G performance	23	105.96	19	325	85.84

Table 2 shows the descriptive statistics for body composition and super-G performance in girls, with the most considerable within-group differences in body weight, thigh circumference, fat mass percentage, chest circumference, and super-G points, as well as minor differences in body height, body mass index, and muscle mass percentage.

Table 2: Descriptive statistics for girls

Variables	N	Mean	Min	Max	SD
Body height	19	165.07	159.4	174	3.87
Body weight	19	57.88	46.5	74.8	7.29
Thigh circumference	19	57.12	48.2	71.1	5.42
Waist circumference	19	76.01	64.7	86.6	5.55
Chest circumference	19	93.56	81.9	104	5.9
Shoulder circumference	19	88.25	82.5	96.9	4.83
Muscle mass percentage	19	25.38	21.74	31.83	2.52
Fat mass percentage	19	11.45	5.1	19.3	3.91
Body mass index	19	20.82	17.44	24.74	2.23
Body fat percentage	19	13.48	12.1	15.4	0.92
Super-G performance	19	131.95	58	360	74.87

Comparison between the genders shows differences in body height, with girls averaging 165.1±3.9 cm compared to boys at 170.1±7.3 cm, and more variation in the boys' height. Body weight differences are also noted (boys 60.7±10.99 kg, girls 57.9±7.3 kg). Thigh circumference is higher in girls (57.1±5.4 cm) than in boys (55.5±6.6 cm), which is somewhat surprising given the expectation of greater lower limb muscle mass in boys. Waist circumference shows no significant difference (boys 75.8±6.7 cm, girls 76.0±5.6 cm). Boys have a smaller chest circumference (89.7±7 cm) than girls (93.6±5.9 cm) due to gender differences in body constitution. Boys' shoulder diameter is more significant (94±11 cm) than girls' (88.3±4.8 cm), with more variation in boys due to more significant biological differences in this age group.

Boys generally have a higher muscle mass percentage (29.9±5.5%) than girls (25.4±2.5%), with more significant variation in boys. Conversely, girls have a

higher fat mass percentage (11.5±3.9%) than boys (6.6±3.5%). Consequently, the body fat percentage is higher in girls (13.5±0.9%) than in boys (9.5±1%). These results are expected to reflect the increased muscle mass in boys during puberty and the slightly increased fat mass in girls. The boys' body mass index is 20.9±2.7, while the girls' is 20.8±2.3, indicating no significant gender differences. Higher muscle mass positively affects overcoming physical exertion, which is considerable in alpine skiing, especially in the speed disciplines.

Table 3: Correlation of body composition variables with the boys' super-G performance (r - Pearson correlation coefficient; r^2 - determination coefficient)

Variables	r	r^2	p
Body height	0.499	0.249	0.015
Body weight	0.650	0.422	0.001
Thigh circumference	0.550	0.302	0.007
Waist circumference	0.433	0.187	0.039
Chest circumference	0.593	0.351	0.003
Shoulder circumference	0.503	0.253	0.015
Muscle mass percentage	0.711	0.505	0.000
Fat mass percentage	0.274	0.075	0.206
Body mass index	0.494	0.244	0.017
Body fat percentage	0.497	0.247	0.016

In Table 3, the Pearson correlation coefficients and determination coefficients show the relationship between the body composition variables and Super-G performance. For boys, the highest and most significant correlations ($p<0.05$) were found with body weight ($r=0.65$; $r^2=0.422$), thigh circumference ($r=0.55$; $r^2=0.302$), chest circumference ($r=0.593$; $r^2=0.351$), and muscle mass percentage ($r=0.711$; $r^2=0.505$). Moderate and significant correlations ($p<0.05$) were observed with shoulder circumference ($r=0.503$; $r^2=0.253$), waist circumference ($r=0.433$; $r^2=0.187$), body height ($r=0.499$; $r^2=0.249$), body mass index ($r=0.494$; $r^2=0.244$), and body fat percentage ($r=0.497$; $r^2=0.247$). The lowest correlation was with fat mass percentage ($r=0.274$; $r^2=0.075$), which was not statistically significant ($p>0.05$).

Table 4: Correlation of body composition variables with girls' super-G performance (r - Pearson correlation coefficient; r^2 - determination coefficient)

Variables	r	r^2	p
Body height	0.272	0.074	0.26
Body weight	0.299	0.089	0.214
Thigh circumference	0.321	0.103	0.181
Waist circumference	0.461	0.212	0.047
Chest circumference	0.419	0.175	0.075
Shoulder circumference	0.392	0.153	0.097
Muscle mass percentage	0.438	0.192	0.06
Fat mass percentage	0.218	0.047	0.37
Body mass index	0.287	0.082	0.233
Body fat percentage	0.469	0.220	0.043

The results in Table 4 show that only waist circumference (r=0.461; r^2=0.212) and body fat percentage (r=0.469; r^2=0.22) significantly correlated ($p<0.05$) with the girls' Super-G performance. No statistical significance ($p>0.05$) was noted in chest circumference (r=0.419; r^2=0.175), shoulder circumference (r=0.392; r^2=0.153), muscle mass percentage (r=0.438; r^2=0.192), and other variables with the lowest correlations.

Table 5: Multiple linear regression analysis of body composition variables with boys' and girls' U16 super-G performance

Gender	r	r^2	SE_E	t	p
Boys	0,854	0,729	60,456	0,801	0,439
Girls	0,77	0,593	71,607	0,694	0,507

Legend: r – correlation coefficient; r2 – determination coefficient; SEE – standard error of the estimate; p – statistical significance of the regression model.

The relationship between the whole set of body composition variables and U16 Super-G performance is shown in Table 5. No statistical significance was found in either regression model (boys: p=0.439; girls: p=0.507). A high correlation was noted between the body composition variables and Super-G

performance in both genders, explaining 73% of the boys' and 59% of the girls' performance. In both genders, it can be concluded that individual variables do not have a significant impact on competitive performance. This is also the reason why individual predictors are not specifically presented in Table 5.

DISCUSSION

Alpine skiing is one of the most complex and specific sports, influenced by numerous factors (Ferland & Comtois, 2018; McKnight, 2018). This study examined the relationship between physical characteristics and young alpine skiers' Super-G performance. Selected parameters (body height, body weight, thigh, waist, chest, and shoulder circumferences, muscle mass percentage, fat mass percentage, body mass index, and body fat percentage) are crucial, alongside skiing technique, motor skills, talent, and environmental factors, in influencing Super-G performance.

Significant correlations were found between the body composition variables and Super-G performance in both U16 boys and girls. For the boys, performance correlated with body weight, thigh circumference, chest circumference, and muscle mass percentage. Lower correlations were noted with body height, body mass index, and body fat percentage. Among the variables, muscle mass percentage has the highest coefficient of determination, explaining 50% of the variance with the variable super-G performance. Higher muscle mass enables better force development during turns, a critical factor in competitive success, consistent with Bertozzi et al. (2024). For girls, waist circumference, chest circumference, muscle mass percentage, and body fat percentage showed the highest correlations with performance. Lower correlations were noted with thigh circumference, shoulder diameter, and body height. In girls, body fat percentage has the highest coefficient of determination, explaining 22% of the variance with the variable super-G performance. The fat mass percentage did not correlate with competitive success, contrary to findings that fat mass percentage is linked to speed discipline success in women (Vermeulen et al., 2017).

These results align with other studies in some instances. Bandalo and Lešnik (2012) found that body constitution significantly impacts younger male skiers' competitive success, with taller and heavier boys achieving better results. Lešnik (1999) emphasized the importance of body weight and control in competitive alpine skiing, which is explained by body voluminosity (body mass and circumferences). Bandalo and Lešnik (2012) noted that greater body weight in the U16 category significantly contributes to faster skiing between gates,

impacting competitive success. Greater body weight aids in speed acquisition during direction changes, providing a competitive advantage, as also noted by Bertozzi et al. (2024). Supej (2008) explained that body constitution influences faster sliding on the skis, as speed increases more in heavier competitors due to gravitational force, terrain slope, and friction forces with appropriate body positioning. However, excessive weight due to high-fat mass complicates body control, a key element in alpine skiing (Lešnik, 1999). Aktaş (2024) found that body weight, height, and body mass index negatively correlate with alpine skiing performance in general.

Experts have emphasized the need to focus on activities that increase muscle mass and body weight in young competitors, appropriately adapted to their developmental stage. Skiing technique is also crucial. Snow training should prioritize refining proper turn technique over gate skiing. Effective body weight utilization and good skiing technique contribute significantly to competitive success. Furthermore, it is essential to avoid potential injuries through a correct approach to ski training for children and adolescents, as these injuries often have a decisive impact on the athlete's competitive career (Kresal, Bračun, Tönig, & Amon., 2021).

A fundamental limitation of this study is the small sample size due to the limited number of competitors in this age category. The relatively few Super-G competitions in the season also limit the study, making generalizations difficult. Future research should replicate this study with larger samples, including older and younger age groups, and examine the relationship between physical characteristics and other alpine skiing disciplines.

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