CORRELATIONS BETWEEN MOTOR AND ANTHROPOMETRIC VARIABLES AND THE PERFORMANCE OF YOUNG COMPETITORS IN ALPINE SKIING

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ABSTRACT

In alpine skiing we encounter many factors that affect the competitor to a greater or lesser extent and must be overcome or exploited in various ways. Broadly speaking, the nature of the activity plays its role just like the equipment, the spectators, the coach, etc., but the most important role is played by the competitor himself. Optimal synthesis is required for successful participation of top competitors with regard to physical, psychological and social skills and characteristics.

During the transformation process (training) we help the competitor with different methods and means to transform from the initial to the final state, which is basically conscious transformation of numerous skills and characteristics of the competitor with impact on their personality as well.

In this study we wanted to establish the extent to which certain anthropometric and motor skill parameters are related to competitive performance of younger boys aged 12 to 13 years in the Rauch Cup in the season 2014/15. Based on the measurements of seven tests of motor skills (MSKOK10 – Ten jumps with both feet, TESJCAS – Squat jump, MS20NVZP – 20m sprint, TREAOPTO – Optojump – Squat jump, MT400 – 400m run, MROS - Equilibrium stability index, and SKI9 – Figures-of-eight around 9 pins) and one measurement of anthropometric dimension (ABMI - Body Mass Index), we used the Pearson correlation coefficient to determine the correlation between individual variables and the performance of a sample of 34 young competitors in alpine skiing. The correlation of the whole set of variables regarding performance was determined using regression analysis. We have established a statistically significant correlation between the number of

achieved points and variables MSKOK10, MS20NVZP, MT400 and SKI9 at the risk level of 1%. In the cases of TREAOPTO, MROSI and TESJCAS the correlation coefficients did not show statistically significant correlation. For the set of motor and anthropometric variables we have established a high and statistically significant linear correlation to the criteria (R=0.76, p=0.003). We have also established that the linear correlation between all motor skill variables and performance is high (R=0.72, p=0.006). The findings of this study show the suitability of the chosen variables in determining the potential success of young alpine skiers.

Keywords: *alpine skiing, young competitors' performance, motor abilities, anthropometry*

POVEZANOST ANTROPOMETRIČNIH IN MOTORIČNIH SPREMENLJIVK Z USPEŠNOSTJO MLAJŠIH DEČKOV V ALPSKEM SMUČANJU

IZVLEČEK

V raziskavi smo ugotavljali, v kolikšni meri so določeni antropometrični in motorični parametri povezani s tekmovalno uspešnostjo mlajših dečkov na tekmovanjih za pokal Rauch v sezoni 2014/15. Na podlagi meritev sedmih testov motoričnega prostora (MSKOK10, TESJCAS, MS20NVZP, TREAOPTO, MT400, MROSI, SKI9) in ene meritve antropometričnega prostora (ABMI), smo s pomočjo Pearsonovega korelacijskega koeficienta ugotavljali povezanost posameznih spremenljivk z uspešnostjo za vzorec 34 mlajših dečkov, ki so bili v smučarski sezoni 2014/15 stari 12 oz. 13 let. Povezanost celotnega sklopa spremenljivk motoričnih in antropometričnih prostorov s tekmovalno uspešnostjo smo ugotavljali s pomočjo regresijske analize. Kriterijsko spremenljivko Tekmovalna uspešnost je predstavljalo skupno število doseženih točk šestih pokalnih tekmovanj za pokal Rauch v sezoni 2014/15. Ugotovili smo, da statistično značilna povezanost med številom doseženih točk in spremenljivko ABMI ne obstaja. Stopnja povezanosti je neznatna in negativna (r = -0,023). Ugotovili smo, da obstaja statistično značilna povezanost med številom doseženih točk in spremenljivkami MSKOK10, MS20NVZP, MT400 in SKI9 pri stopnji tveganja 1 %. V primeru TREAOPTO, MROSI in TESJCAS izračun korelacijskih koeficientov ni pokazal statistično značilne povezanosti. Za sklop vseh motoričnih in antropometričnih spremenljivk smo ugotovili, da je linearna povezanost s kriterijem visoka (R=0,76, p=0,003). Ugotovili smo tudi, da je linearna povezanost med vsemi motoričnimi spremenljivkami hkrati in kriterijem visoka (R=0,72, p=0,006). Ugotovitve raziskave kažejo na ustreznost izbire spremenljivk pri ugotavljanju potencialne uspešnosti mladih alpskih smučarjev.

Ključne besede: *alpsko smučanje, uspešnost mladih tekmovalcev, gibalne sposobnosti, morfologija*

INTRODUCTION

Modern skiing (alpine skiing) is a complex, high-speed winter sport. Dynamic changes and operational structures impose increasing requirements on athletes - a solid base of technical skills, physical, tactical, and psychological training. An alpine skier is first and foremost an athlete whose body should function synchronously, like a perfect mechanism, in the specific conditions of the different disciplines of alpine skiing and depending on a wide variety of environmental variables, to be able to achieve their athletic potential (Kostadinov & Yordanov, 2021). Alpine skiing is a winter sport that involves individual descents on snow slopes with pre-determined ski routes using skis and attached bindings. The competitions are organized according to a certain order, in which all competitors see the results at the end of the competition (Toma et al., 2019). There are many factors that affect the competitor to a greater or lesser extent and must be overcome or utilized in various ways. The skier's successful performance depends on many variables. Alpine skiing is one of the most complex disciplines to analyze as the skier trajectory is curved and the athlete is moving within a broad open space, down the slope according to the directions and finish, the snow/snow base (moving the body upwards and downwards) and gates (left and right movement) (Erdmann et al., 2017). Generally, the natural environment with various weather conditions plays just as important a role in competitive alpine skiing as the equipment, the spectators, the coach, etc. However, the most important are the competitors themselves. Optimal synthesis is required for successful participation of top competitors with regard to physical, psychological and social skills and characteristics. During the transformation process (training) we help the competitor with different methods and means to transform from the initial to the final state, which is basically conscious transformation of numerous skills and characteristics of the competitor with impact on their personality as well (Petrović, Šmitek & Žvan, 1983). According to Petrović et al. (1983), the psychosomatic status is defined as multidimensional and suprasummative in terms of its effects, indicating that a change in a certain factor conditions a change of other factors. Human movement depends on human motor functions/mobility, characteristics, and skills according to Pistotnik (2011). Skills are natural human features, representing the level of utilization of different body management systems for achieving the movement objectives set. It can be said that success in alpine skiing largely depends on the degree of accepted and built specific motor skills (Kuna, Franjko, & Males, 2008). The characteristics are dimensions representing the human appearance and their reaction to the environment, whereas skills or knowledge are defined by learning the acquired movement patterns, which are realized on the basis of abilities and characteristics. Motor skills are indispensable components of human physical activity, enabling the potential for specific efforts and utilization of the body's functional potential. They develop naturally up to a certain level, depending on many factors, and can be perfected through practice (Plastoi, 2018). The anthropometric methods, defined as measurement of the dimensions of the human body, also have a significant impact on successful competitive alpine skiing (Cramer & Rayan, 2012). Hadzic, Bjelica, Georgiev, Vujovic, and Popovic (2014) analyzed the

differences in the basic turn technique as one of the ski school elements with regard to anthropometric characteristics. It has been demonstrated that there is a statistically significant difference in the technique of the basic turn with regard to the anthropometric characteristics of the subjects. Petrović et al. (1983) stated that the ability to kinetically solve spatial problems and timing ability are especially important for alpine skiing, because skiing involves, among other things, different speed combinations of gates and, above all, uneven terrain formation. It could be argued that success, even among young athletes, is mainly the result of properly planned training, talent and hard work. There are only a few who tolerate the psychophysical efforts well and maintain long-term motivation, and even fewer who respond positively to challenges by adapting and making the changes necessary for later top achievements (Bačanac & Škof, 2007). Even in alpine skiing, performance reflects the entire personality of the competitor and must be addressed in a sufficiently complex manner. It consists of several individual skills used under given performance conditions (Ehlenz, Grosser & Zimmermann, 1985). In this study we aimed to establish the extent to which certain anthropometric and motor skill parameters are related to competitive performance of younger male skiers.

METHODS

The measurements were performed on September 20, 2014 at the Faculty of Sports, University of Ljubljana (Slovenia), in the morning. Students and alpine skiing instructors of the Faculty of Sports, University of Ljubljana assisted in measuring, setting up and organizing. As part of the regular measurements, carried out twice a year, several anthropometric, motor, psychological dimensions and other parameters were measured, among which we focused on seven motor and one anthropometric dimension. The measurement was performed in the lobby of the faculty before the subjects headed for warmup to perform motor skill test at the faculty hall, and later for a sprint and 400-meter run at the athletic stadium.

Participants and recruitment

The study included a sample of 34 younger boys who competed in the Rauch Cup in slalom, giant slalom and super giant slalom during the season 2014/15. The overall number of competitors was larger, but only 34 were anthropometrically measured and had their motor skills measured at the Faculty of Sports in October 2014, on account of having achieved a ranking and consequently points at the Rauch Cup. Certain individuals did not take part in the measurements for subjective reasons. Therefore, we excluded from the sample all those who were not the subject of measurements and those who did not score points during the 2014/15 season. 21 subjects were born in 2001, the other 13 in 2002, belonging to the age categories of 12 and 13 years.

Measurement procedures

The measurements performed at the Faculty of Sports covered several different anthropometric and motor skills, of which we focused on the following eight:
– Anthropometric Body Mass Index (ABMI)
– Ten jumps (MSKOK10)
– Squat Jump – Tensiometer (TESJCAS)
– 20-meter sprint – start with legs parallel (MS20NVZP)
– Squat Jump – Optojump (TREAOPTO)
– 400-meter run (MT400)
– Stability Index – Biodex (MROSI)
– Figures-of-eight around 9 pins (SKI9)

The criterion variable is the actual performance of all measured competitors at the Rauch Cup during the 2014/2015 season. It is expressed as a total of points in the Rauch Cup competitions. During this season, 2 slalom, 3 giant slalom and 1 super giant slalom races were successfully held at the Rauch Cup, the results of which were considered in the scoring for the final ranking. In these competitions, the ranked competitors achieved a certain number of points for a certain ranking determined by the Skiing Association of Slovenia.

Statistical analysis

We used the SPSS program - Statistical Package for Social Sciences (IBM Corporation, Armonk, New York, USA) for the statistical data processing. The normality of data was confirmed using the Shapiro-Wilk test. When processing basic statistics of independent variables, we determined the minimum value, the maximum value, the range between the minimum and maximum values, arithmetic mean, and standard deviation. To determine whether we could set the selected variables as comparative performance units of the Rauch Cup, we calculated the Pearson correlation coefficient for each of the eight selected variables in relation to the subjects' performance.

RESULTS

The first part of data presentation displays the calculation of basic statistics for anthropometric and motor variables. In the second part of data analysis, we demonstrated the calculation of the Pearson correlation coefficients between individual anthropometric variables and motor skills in relation to the criterion variable (points at the Rauch Cup competition). The third part represents the calculation of the correlation of all variables with the criterion, for which we performed the regression analysis and

calculated the multiple correlation coefficient. The same principle of data presentation was applied for the set of motor variables.

Table 1. The results of basic statistics of anthropometric and motor variables for younger boys.

	N	**RANGE**	**MIN**	**MAX**	**AM**	**SD**
ABMI	36	10.3	15.3	25.6	19.88	2.65
MSKOK10	36	9.64	16.04	25.68	19.54	2.23
TESJCAS	36	346	238	584	365.35	75.61
MS20NVZP	36	1.99	5.59	7.58	6.64	.45
MT400	36	34.58	65.56	100.14	79.08	7.94
MROSI	36	3.2	.6	3.8	1.50	.73
SKI9	36	8.1	28.2	36.3	3182	2.16
TREAOPTO	36	.220	.374	.594	.467	.05

Note: N = number of subjects; Range = range between minimal and maximum value; MIN = minimal value; MAX = maximum value; AM = arithmetic mean; SD = standard deviation. The acronyms of variables (test) are explained in the chapter Independent Variables Sample.

As can be seen from Table 1, the ABMI values differ between the subjects, specifically for 10.3. Such a wide range can be explained by the age of the subjects, as they were born in 2001 or 2002. In this phase of the pre-puberty period, accelerated growth can occur in some individuals while physical development is slightly delayed in others. The results of the basic statistics of motor variables also show that the values for most of the motor skill variables are less scattered, which is mainly indicated by the low values of the standard deviation. A somewhat greater dispersion of results only can be detected in the MROSI variable (AM=1.5; SD=0.73)

AMBI (body mass index) and performance (points) in the Rauch Cup.

The calculation of the Pearson correlation coefficient showed that there is no statistically significant correlation between the number of points achieved and the ABMI variable. The correlation level is insignificant and negative (r = - 0.023).

Table 2. The Pearson correlation coefficient values between motor skill variables and performance (points) in the Rauch Cup.

TEST		POINTS
MSKOK10	r	.577**
	Sig. (2--tailed)	.000
TESJCAS	r	-.106
	Sig. (2--tailed)	.552
MS20NVZP	r	.611**
	Sig. (2--tailed)	.000
MT400	r	-.513**
	Sig. (2--tailed)	.002
MROSI	r	.259
	Sig. (2--tailed)	.139
SKI9	r	-.477**
	Sig. (2--tailed)	.004
TREAOPTO	r	-.161
	Sig. (2--tailed)	.362

*Note: Sig. = statistical significance of correlation; ** = correlation is statistically significant at the risk level of 1%; r = Pearson correlation coefficient.*

Table 2 presents the Pearson correlation coefficients for motor space in relation to performance (points). It shows that there is a statistically significant correlation between the number of points achieved and the variables MSKOK10, MS20NVZP, MT400 and SKI9 at a risk level of 1%. In the cases of TREAOPTO, MROSI and TESJCAS, the calculation of correlation coefficients did not show a statistically significant correlation.

Table 3. The result of the correlation of all anthropometric and motor skill variables with performance (points) in the Rauch Cup.

R	R2	Adjusted R2	Sig F
.752a	.566	.427	.003

Note: R = correlation coefficient; R2 = coefficient of determination; Adjusted R2: adjusted coefficient of determination; Sig F = statistical significance of correlation; a = predictors: constant (POINTS), ABMI, TREAOPTO, MROSI, TESJCAS, MT400, SKI9, MSKOK10.

It is evident from Table 3 that the coefficient of multiple correlation is R = 0.752, indicating that the linear correlation between all variables and the criterion is high. The correlation between all variables and performance is statistically significant (Sig F = 0.003). The coefficient of determination is R2 = 0.566, which means that 56.6% of the performance variance can be explained by motor skill and anthropometric variables.

Table 4: The result of the correlation between all motor skill variables and performance (points) in the Rauch Cup.

R	R2	Adjusted R2	Sig F
.716a	.512	.381	.005

Legend: R = correlation coefficient; R^2 = coefficient of determination; Adjusted R^2 = adjusted coefficient of determination; Sig F = statistical significance of correlation; ^{a} = predictors: constant (POINTS), TREAOPTO, MROSI, TESJCAS, MT400, SKI9, MSKOK10, MS20NVZP.

The multiple correlation coefficient is R = 0.716, which indicates that a linear correlation between all motor skill variables at the same time and the criterion is high, as can be seen in Table 4. The correlation between all motor skill variables and performance is statistically significant (Sig F = 0.005). The coefficient of determination is R2 = 0.512, which means that 51.2% of the performance variance can be explained by motor skill variables.

DISCUSSION

Studies establishing a correlation between various dimensions of an athlete's psychosomatic status and their performance undoubtedly represent the foundation for potential changes and qualitative improvement in various fields, especially concerning the successful and healthy development of an athlete. Since alpine skiing is a complex,

individual-structural sport, many different factors have an impact on the competitor. Success in this sport depends on an optimal combination of physical, psychological, and social dimensions. It is known that movement skills are the most reliable predictors of potential success, and anthropometric characteristics do not fall behind much in importance.

Through a transformation process, we achieve changes in the psychosomatic status of the competitor. Because it is multidimensional and suprasummative (Petrović et al., 1983), a change in one factor causes a change in other factors. The level of the subjects' development is substantially related to the competitive performance in the category of younger boys, because some of them experience accelerated growth of individual parts of the body at that age. This can have a positive as well as a negative effect on motor skills. Development in individuals may also be delayed, depriving them of movement skills, which can be particularly pronounced in sports. Petrović et al. (1983) state that the transformation process can have an inhibitory effect on certain abilities and characteristics during the growing-up phase. In the present study, we were interested in the direct correlations between motor skills and anthropometric characteristics and competitive performance for the category of younger boys in alpine skiing. The goal was to determine the correlation level between an individual motor skill and anthropometric variables and competitive performance as well as the impact of all selected motor skill and anthropometric variables on competitive performance.

Further, we calculated the correlation between the entire set of motor skill variables and the performance of the competitors at the Rauch Cup. During the analysis of the basic statistics, we determined that the Body Mass Index values vary considerably among the subjects, which is most likely the result of the already mentioned differences in the stages of development. The calculation of the Pearson correlation coefficient showed that the correlation between the Body Mass Index and performance is negligible ($r = -0.023$) and statistically insignificant, which confirms the assumptions regarding the differences in development in the considered age category. We found that in our sample the 20-meter sprint from a high start with legs parallel (MS20NVZP) is mostly related to competitive performance ($r = 0.611$) and that the correlation is statistically significant (Sig F = 0.000).

The test assesses the basic movement ability of speed and is also mainly related to explosive power (acceleration at the start). A similar level of correlation ($r = 0.577$) and statistical significance (Sig F = 0.000) was achieved by the ten-jump test (MSKOK10). It indicates the repetitive explosive force as a manifestation of the energy component of power. Especially in slalom and giant slalom, this phenomenon is expressed when connecting relatively short turns and relying on repetitive power for speed control and (lateral) relief.

The MT400 ($r = -0.513$) and SKI9 ($r = -.477$) tests, which are negatively correlated to competitive performance, revealed a statistically significant correlation. A 400-meter run expresses speed endurance, which is defined by the energy component of the movement and prevails in efforts of up to two minutes. The test is physiologically related to the duration of the activity on the track. SKI9 is the only test in our study that represents

special motor skills, i.e., agility, which is defined by rapid changes of direction as a manifestation of coordination. It is also defined by explosive power and speed (Petrović et al., 1983), which is also evident if we follow the course of the test. Among the previously presented statistically characteristic correlations, SKI9 is the only variable that belongs to the subspace of the informational component of movement.

Because it is a distinctly skiing test, we expected a similar result. The results of motor skill tests and anthropometric measurements presented so far were not surprising. We find it all the more interesting that the correlation of the variable TESJCAS (squat jump on a tensiometer) is not statistically significant and that it stands in a negative, insignificant correlation with performance ($r = -0.016$). A particularly interesting fact is that we measured explosive thrust power with this test and expected higher correlation values, similar to those in the ten jumps test. The findings of this study do not comport with the findings of the study conducted by Lešnik and Žvan (2000), who found a statistical significance for two tests of explosive power (triple jump and standing long jump), but for another generation of competitors. The balance and stability test (MROSI) revealed a low ($r = 0.259$) and statistically insignificant correlation with the criterion variable. Obviously, balance in the considered age categories does not yet affect performance, as can also be seen in the study by Lah (2014), who investigated the impact of balance between the categories of younger and older boys and girls on the performance in alpine skiing. The correlations were insignificant for all four groups of subjects. The last studied test of motor skill dimensions was a squat jump between the bars of the OPTOJUMP device (TREAOPTO), which was defined by reaction speed. It revealed a negligible negative correlation ($r = -0.161$) and statistical insignificance. For the entire set of all studied variables, we found that there is a statistically significant correlation (Sig F = 0.003) with performance at the competition ($R = 0.752$). The coefficient of determination was $R2 = 0.566$, which means that 56.6% of the performance variance can be explained by motor and anthropometric variables. The set of all motor variables, which we additionally calculated, is statistically significantly correlated (Sig F = 0.005) with competitive performance ($R = 0.716$). We were therefore able to explain the 51.2% of the performance variance with motor skills variables ($R2 = 0.512$), which represents a slightly smaller share than for the set of all variables.

From the obtained results of the set of all variables and set of motor skill variables, we can conclude that the Body Mass Index (ABMI) itself is not statistically significantly related to the points; however, as a whole (together with the motor skill variables) it clearly contributes to the proportion of explained variance.

The present study rebutted the findings of Lah (2014), who determined a weak and uncharacteristic correlation between balance (MROSI) and competitive performance. For the variable TREAOPTO (reaction speed), and especially for the variable TESJCAS (explosive power), we expected higher correlation values and statistical significance. However, the results of the basic statistics of these three dimensions varied considerably, which we tried to explain with the differences in the development level of the studied age category and with the assumption that not all competitors have the same predispositions, opportunities and desire for successful participation in top alpine

skiing. Since the sample represented an already selected population, De Costa (2009) similarly drew attention to the fact that currently children are directed to alpine skiing based on social criteria and increasingly less on motor skill criteria.

To consider theory and practice, it can be said that the findings of the present study represent a foundation for further research, as balance, reaction speed and explosive thrust tests did not show any statistical significance. In their study, Bandalo and Lešnik (2011) proposed to reduce the number of variables from the battery of tests for determining motor skills and anthropometric characteristics in the future. We support this idea; however, in the future, regular studies in this field are required to determine important motor and anthropometric dimensions and tests, because Bandalo and Lešnik (2012) established in their study that over a period of four years (2007 to 2010) the correlation between anthropometric and motor skill variables and performance varied.

CONCLUSION

We established a statistically significant value of the multiple correlation coefficient ($R = 0.752$), which means that 56.6% of the variance of the actual performance can be explained by the considered motor skill and anthropometric variables ($R2 = 0.566$).

Today's (sedentary) lifestyle and greater involvement of young people in other non-sport fields, together with the relatively high costs of skiing and ski training, which often do not allow the parents to enroll their children in ski schools, result in a fundamentally limited selection process. We will not change this fact with our research, but we can conclude that not all competitors who were the subjects of measurement at the Faculty of Sports are part of the skiing circuit on account of extremely positive physical reasons.

On the other hand, having considered a sample of younger boys, we can conclude that the stage of development plays an important role in the separation of the physically more successful from the physically disadvantaged competitors. Therefore, it is necessary to pay special attention to the latter in terms of social and psychological support. We have proposed the idea of managing the mentioned groups of competitors separately during the transformation process, although it is clear that in practice this may be problematic. Undoubtedly, with a proper mindset and efforts we can ensure less discomfort or neglect among young ambitious competitors.

In the future, it will be necessary to monitor the development of young athletes even more systematically. 12 - 13 years is a sensitive period, which is why it is all the more important that the battery of tests is effective and provides information about the athlete necessary for the professionals in the field to guide them properly during the training process. The fact remains that many other areas contribute to competitive performance, such as psychological preparation, personality traits, as well as tactical preparation. In any case, it would be necessary to include in future studies the aspect of skiing techniques, which has already been shown to be necessary in past studies (Puhalj, 2018).

Our findings show that we are on the right track. Therefore, we will continue with the introduction of the most up-to-date measurement methods and try to connect them with the measurements performed in the older age categories of competitors in alpine skiing.

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