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Original scientific paper

Relations of Biomotor Structures and Performance of Technical Elements of Alpine Skiing in Croatian Ski Instructors

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A B S T R A C T

With the aim of identifying the factors of alpine skiers' biomotor status in predicting their specific skills, three variable sets were used, comprised of the total of 24 measures (9 variables for assessing anthropometric characteristics, 8 variables for assessing motor abilities and 7 variables for assessing specific ski skills of alpine skiing), on a sample of 79 ski instructor candidates. After preliminary analysis procedures which included descriptive operations and factorization of each separate space, relations between the obtained latent dimensions were established by correlation analysis. The extracted varimax factors were defined as follows – three factors in the morphology space: V1 – Voluminosity and transverse dimensionality of the skeleton, V2 – Longitudinal dimensionality of the skeleton, V3 – Subcutaneous fat tissue; 2 factors in the space of motor abilities: V1 – Agility and explosive power, V2 – Static strength and balance; while a general factor of Specific motor skills of alpine skiing was isolated in the space of motor skills. Statistically significant positive correlation was found between agility and explosive power and general factor of skiing skills, which means that agility and explosive power are the basis for quality performance of advanced and competitive techniques in alpine skiing. Namely, in realization of advanced and competitive techniques of alpine skiing, which imply a high level of skiing skills acquisition and full automatization of performance, all actions are performed by fast and explosive movement direction changes.

Key words: *biomotor status – motor abilities, morphology, ski skills, relations, ski instructors*

Introduction

Success in alpine skiing, apart from the skiing motor skills, also depends on biomotor development of the skier, and primarily on the level of motor and functional abilities (agility, coordination, balance, speed, strength, and aerobic and anaerobic endurance). Specific functional--motor sets are typically reflected here through the morphological subsegment, which indicates the existence of integrative effects of anthropological characteristics on motor functioning. In order for orientation and selection in alpine skiing to be efficient, it is necessary to determine which abilities and/or characteristics have decisive influence on performance of specific skiing techniques in alpine skiing. It is important to emphasize the distinct complexity of alpine skiing, which can be classified in line with those activities which take place in specific and complex conditions of the external environment. During skiing, there is a constant danger of losing balance (which depends upon the friction between the ski edge and snow surface), extremely variable accelerations and varying moments of inertia of the overall system or its particular segments[1]. Therefore, skiing quality of competitive skiers, as well as ski instructors, is reflected primarily through a high level of specific motor skills which have a dominant and complex effect on situational efficiency. It is a known rule that the lack of knowledge about the movements which are to be performed within the motor programme results in irrationality of performance[2]. Such irrationality necessarily requires addi-

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tional energy consumption. As early as 1952, Guthrie[2] stated that the improvement of motor skills reflects on the increase of movement performance accuracy, reduction of energy consumption, and sometimes the reduction of the overall time necessary for movement performance. However, motor skills, apart from the direct impact on skiing quality of ski instructors, also have an indirect effect through interaction relations with other relevant dimensions of anthropological status. Andersen and Montgomery (1988)[3] established that high level of skill in skiing defines better utilization of glycogen from slow twitch muscle fibres.

Therefore, it can be said that quality of ski instructors is determined by suprasummative effects of all relevant factors which determine success in alpine skiing. That is why it is important to determine the relationship between functional-motor abilities and anthropometric characteristics and skiing quality in ski instructors.

Materials and Methods

Variable sample included 79 skiers who participated in specialist education for ski instructors organized by the Croatian Snow Sport Instructors and Trainers Association (HZUTS). The subject sample was partly stratified, and it can be considered a subset of the total population of ski instructors, i.e., representative of the population which is defined exclusively by the level of skiing skills. Precisely because of this, the results obtained on such a sample can be generalized to the wider population of ski instructors.

Variable sample

Variables for assessing morphological characteristics

The set of predictor variables consisted of 9 standard morphological measures[4–7], which were defined as good representatives of latent anthropometric dimensions. The following measures were applied: *For assessing longitudinal dimensionality of the skeleton*: Body height and Foot length; *For assessing transverse dimensionality of the skeleton*: Wrist diameter and Ankle joint diameter; *For assessing body mass and volume*: Body mass, Thigh circumference and Forearm circumference; *for assessing subcutaneous fat tissue*: Triceps skinfold and Calf skinfold.

Variables for assessing motor abilities: The structure of motor space in ski instructors was determined by the activities they should perform successfully, and which are complex and demanding. It is known that a high level of basic motor abilities is a precondition for successfull acquisition of new motor information, their improvement and application.

In order to allow the assessment of basic motor abilities, a battery of 8 standard motor measuring instruments was selected. Since activities of ski instructors in the space of motor abilities are mainly based on movement structures which require highly developed agility, balance, psychomotor speed and strength, the selected variables are best for assessing the aforementioned abilities. The selection of variables was done based on studying a number of previus research studies conducted on different populations[5,8–11]. The following measuring instruments were applied: *For assessing agility*: Figure-of-eight with a bend and Slalom run; *For assessing movement frequency*: Foot tapping; *For assessing explosive power*: Standing broad jump; *For assessing repetitive and static strength*: Trunk bending and Half squats; Standing sideways on a balance beam with both feet and Hopping on a balance beam.

Variables for assessing discrete and serial motor skills of alpine skiing: Success in performing discrete motor skills in alpine skiing was, in accordance with methodological requirements and related previous research[6,12], assessed by judges based on videorecording. Therefore, the assessment of success for each test of discrete motor skills was done by five judges, independently from each other, on a five-point Likert scale. The following variables were analyzed: Short slalom curves, Dynamic parallel turn (Carve turn); Off piste skiing, Deep snow skiing; Slalom skiing; Giant slalom skiing and Obstacle course skiing.

Descriptive statistics were calculated for all variables. After preliminary analysis procedures, factor analysis was applied separately for each of the three variable sets. Finally, in accordance with the main goal of the research, relations between the isolated latent variables were calculated by correlation analysis.

Results and Discussion

Based on previous research studies[6,13], it can be inferred that ski instructor candidates had averagely the same body height as elite Austrian skiers, and were averagely taller than Croatian national demonstrators. As to the body mass, ski instructor candidates had lower body mass and greater thigh circumference in comparison to elite Austrian skiers, while they were very similar to Croatian national demonstrators in their soft tissue structure. Therefore, based on basic descriptive parameters, it can be assumed that morphological structure of elite alpine skiers differs from the structure of ski instructors, whereas ski instructors generally do not differ from demonstrators. Why is this so? Probably because successful alpine skiers train every day, and such systematic training is reflected through the morphological subsegment, differentiating them from ski instructor candidates, as well as ski demonstrators, who are much less kinesiologicaly engaged. Namely, periodical activity of ski instructors and demonstrators, primarily during the winter period, does not require top physical fitness and achievement of top results in skiing, which is certainly a limiting factor in reaching maximum biomotor development forms.

Since a battery of tests for assessing functional-motor abilities used in the present research has not been used in available previous research studies on alpine skiers, it is difficult to draw a concrete comparison of results.

TABLE 1
BASIC STATISTICAL PARAMETERS OF MORPHOLOGICAL CHARACTERISTICS, MOTOR ABILITIES AND DISCRETE AND SERIAL MOTOR SKILLS OF ALPINE SKIING IN SKI INSTRUCTOR CANDIDATES (N=79)

Variables	Min	Max	X	SD
Body mass	56.20	114.70	80.97	11.63
Body height	169.00	201.50	182.38	6.37
Foot lenght	24.00	31.50	27.19	1.34
Wrist diameter	4.90	6.43	5.67	0.35
Ankle joint diameter	6.43	8.57	7.49	0.43
Forearm circumference	22.00	32.00	27.68	1.77
Thigh circumference	48.00	66.83	58.33	4.08
Triceps skinfold	3.80	17.73	10.50	3.69
Calf skinfold	5.20	30.87	13.16	4.62
Figure-of-eight with a bend	14.61	25.60	17.91	1.68
Slalom run	6.23	8.82	7.36	0.56
Foot tapping	32.00	56.00	42.09	4.34
Standing broad jump	152.00	278.00	212.89	23.86
Trunk bending	0.00	60.00	40.72	11.54
Half squat	10.00	301.00	65.65	45.28
Standing sideways on a balance beam with both feet	0.00	22.41	5.14	3.38
Hopping on a balance beam	2.00	8.00	4.51	1.35
Short slalom curves	1.00	3.80	2.41	0.71
Carve turn	1.00	4.00	2.37	0.69
Off piste skiing	1.00	3.80	2.36	0.62
Deep snow skiing	1.00	4.00	2.39	0.83
Slalom skiing skill	1.20	4.60	2.58	0.81
Giant slalom skiing skill	1.20	4.80	2.58	0.77
Obstacle course skiing skill	1.00	3.60	2.04	0.63

Min – minimum result, Max – maximum result, X – mean, SD – standard deviation

However, even by cursory analysis, it can be assumed that the population of ski instructor candidates is represented by a group which could be generally classified, based on basic motor abilities, as a group of untrained skiers. Namely, after examining the test results of repetitive and static strength, a disproportion in the results is clearly seen, indicating a low level of psychophysical fitness. Similar results can be found in populations similar to the one treated here (e.g., in army recruits[14]), which can be considered a representative of the general population. The situation is probably similar among all other populations which are homogenized, based on some other parameters and not on the level of basic functional-motor abilities. By examining the result values, it can be assumed that ski instructors who had better results are involved in a regular training process which has affected a more balanced and quality biomotor development. The result level is congruent with the results of kinesiology students[8], or Special Forces members[9].

When observing the mean values of motor skills evaluations, it can be seen that the judges gave the highest evaluations in the giant slalom situational test, followed by the slalom situational test, whereas the lowest evaluation was given to obstacle course skiing and deep snow skiing. Most ski instructor candidates have participated in competitive skiing until recently, so competing in slalom and giant slalom disciplines is almost routine for them, which has led to a high level of demonstration in so called competitive variables during the testing, which are ultimately a steady referent value of the overall biomotor status of alpine skiers.

Research studies investigating the structure of morphological characteristics in populations whose growth and development has reached definitive norms yield relatively reliable indicators of final morphological structure and such relations of dimensions which can be considered infinite or permanent. Present research is also one of such studies. Latent structure of relevant morphological dimensions provides useful information about biomotor development, naturally, considering the fact that kinesiological engagement is usually very clearly reflected through morphological structure. By varimax rotation of principal components of morphological variables' intercorrelation matrices, three latent dimensions were isolated in ski instructors: voluminosity and transverse dimensionality of the skeleton, longitudinal dimensionality of the skeleton and subcutaneous fat tissue. Obviously, ski instructors have a morphological structure

which is original in a way and most likely structured by long-standing kinesiological engagement in specific winter conditions. This is why the first varimax factor, which is underlain with muscle tissue development and transverse dimensionality of the skeleton, is the dominant characteristic of ski instructors.

TABLE 2
VARIMAX FACTORS OF MORPHOLOGICAL VARIABLES

Variables	V1	V2	V3
Body mass	0.78	0.45	0.28
Body height	0.20	0.92	0.03
Foot lenght	0.22	0.90	–0.06
Wrist diameter	0.81	0.20	–0.22
Ankle joint diameter	0.54	0.55	–0.03
Forearm circumference	0.90	0.13	0.19
Thigh circumference	0.71	0.24	0.47
Triceps skinfold	0.26	–0.17	0.87
Calf skinfold	–0.07	0.08	0.90
Expl.Var	3.02	2.31	1.97
Prp.Totl	0.34	0.26	0.22

TABLE 3
VARIMAX FACTORS OF VARIABLES ASSESSING MOTOR ABILITIES

Variables	V1	V2
Figure-of-eight with a bend	–0.83	–0.12
Slalom run	–0.81	–0.31
Foot tapping	0.41	0.57
Standing broad jump	0.83	0.08
Trunk bending	0.70	0.17
Half squat	0.06	0.80
Standing sideways on a balance beam with both feet	0.07	0.73
Hopping on a balance beam	0.22	0.27
Expl.Var	2.75	1.72
Prp.Totl	0.34	0.22

TABLE 4
VARIMAX FACTORS OF DISCRETE AND SERIAL SKILLS OF ALPINE SKIING

Variables	V1
Short slalom curves	0.78
Carve turn	0.82
Off piste skiing	0.83
Deep snow skiing	0.72
Slalom skiing skill	0.79
Giant slalom skiing skill	0.82
Obstacle course skiing skill	0.72
Expl.Var	4.28
Prp.Totl	0.61

Kinesiological engagement imminently affects the changes of motor abilities' structure, and specific stimuli, of certain extent and intensity, generally lead to changes in the structure of motor dimensions in such a way that optimum motor structures are formed for performing certain activities, which is the basis of specific motor development.

By varimax rotation of principal components, two motor factors were isolated in ski instructors: the first one with significant projections of variables assessing explosive power and agility, and the second one which is marked by dominant projections of static strength and balance. The first factor in alpine skiers is responsible for the development of agility and explosive power motor abilities. Namely, an alpine skier must constantly change the movement direction rapidly, which is primarily enabled by his/her agility and explosive power. The second factor indicates that static strength and balance are also needed for successful skiing because movement structures are performed in specific skiing stance which implies static strength (primarily of lower extremities), with constant maintenance of optimum stance in very variable conditions.

By varimax rotation of principal components of intercorrelation matrices of variables assessing *discrete and serial skills of alpine skiing* in ski instructors, one latent dimension was isolated which can be defined by general factor of skiing skills. Variable projections on the common factor are high and stabile, and slightly lower values were found in variables deep snow skiing and obstacle course skiing, which are obviously more demanding and their successful performance implies having somewhat higher skiing quality. Generally, the obtained latent structure is pretty logical because the overall skiing efficiency of ski instructors is based exactly on the integration of overall skiing skills, which are the main characteristic of the specific biomotor set in alpine skiing[15]. However, since ski instructors must possess a high level of acquisition of all skiing skills, perhaps this integration, i.e., mutual correlation of skiing skills, is more prominently integrated in this population as opposed to other populations that are involved in alpine skiing in different forms, disciplines, extent and intensity. Therefore, ski instructors, and especially ski demonstrators, are expected to possess automatization levels in performance of all skiing skills, which should have an integrative basis.

By examining Table 5, significant correlation can be noticed between specific motor skills of alpine skiing and agility and explosive power, while correlations of agility and explosive power to voluminosity and transverse dimensionality of the skeleton are negative. Negative correlations, i.e., negative impact of fat tissue on all motor manifestations, can also be clearly seen, although not statistically significant.

Therefore, based on the results obtained by correlation analysis between latent dimensions, it can be concluded that fat tissue has a general negative impact on all

TABLE 5
CORRELATIONS BETWEEN THE DIMENSIONS OF MORPHOLOGY, MOTOR ABILITIES AND SKIING SKILLS

	MORPHOL V1	MORPHOL V2	MORPHOL V3	MOTOR V1	MOTOR V2	SKILLS V1
MORPHOL V1	1.00	0.00	0.00	–0.25	–0.19	–0.13
MORPHOL V2	0.00	1.00	0.00	0.16	–0.08	0.02
MORPHOL V3	0.00	0.00	1.00	–0.20	–0.22	–0.17
MOTOR V1	–0.25	0.16	–0.20	1.00	0.00	0.40
MOTOR V2	–0.19	–0.08	–0.22	0.00	1.00	0.10
SKILLS V1	–0.13	0.02	–0.17	0.40	0.10	1.00

MORPHOL V1 – Voluminosity and transverse dimensionality of the skeleton, MORPHOL V2 – Longitudinal dimensionality of the skeleton, MORPHOL V3 – Subcutaneous fat tissue, MOTOR V1 – Agility and explosive power, MOTOR V2 – Static strength and balance, SKILLS V1 – Specific discrete and serial motor skills of alpine skiing

motor manifestations, which is a known phenomenon in the overall process of biomotor development. This refers both to puberty[16–19], and adulthood[14,20–22]. However, it is important to note here that this impact is slightly smaller in skiing skills which are clearly primarily determined by the level of motor programmes acquisition, which has been proved in previous research studies[6].

The impact of explosive power and agility on general skiing performance is logical and previously explained. As emphasized earlier, in order to successfully perform any skiing figure, and especially a combination of different and demanding skiing elements in variable conditions of external environment, a skier must possess a high level of overall skiing skills. Therefore, all factors which determine successful skiing performance must be fully integrated, only then we can talk about situational efficiency. Moreover, when performing advanced skiing techniques, especially off-piste and competitive skiing, skier's perception must be extremely good, as well as the processing and designing of the the movement programme, because the ski run set must be mastered quickly, with explosive and precise changes of movement direction, which requires, besides a high level of skiing skill, an above average agility and explosive power. Namely, all movements in the kinetic chain must be synchronized constants. Therefore, a skier must act quickly and »work all the time« on mastering the ski run and maintaining a balanced position, and balance in skiing is easily maintained when a skier possesses ideal technique and is capable to perform the inevitable change of movement direction in agile and explosive manner, and above all, precisely and timely. The obtained information about biomotor structures and correlation of separate dimensions of ski instructors' anthropological status indicate the complexity of alpine skiing, which calls for further research interventions.

Conclusion

Ski instructors represent a population of skiers which is the basis for growth, popularization and massification of alpine skiing as an activity which interests millions of people. Because of their role of responsibility, they must constantly improve their skiing skills, and as such, represent an almost ideal population for investigating biomotor development and correlations of separate dimensions of anthropological characteristics in alpine skiing and due to this reason they were selected, as a convenience sample, for this research.

After preliminary analysis procedures, latent structure of relevant anthropological characteristics of ski instructors was determined by factor analysis. It is characterized by 5 stabile dimensions: *morphology*: voluminosity and transverse dimensionality of the skeleton, longitudinal dimensionality of the skeleton, subcutaneous fat tissue; *motor abilities*: agility and explosive power, static strength and balance; and a general factor of s*pecific motor skills of alpine skiing*. Relations between the obtained latent dimensions indicate specific principles of motor functioning in ski instructors, who obviously possess a biomotor set which is generally characterized by a high level of acquisition of motor skills, whose successful performance is enabled, i.e., supported by particularly developed agility and explosive power. Integration of coordination/agility and explosive power predominantly determines specific motor efficiency in sports games[23,24], as well as in combat sports[25–27]. A negative impact of primarily ballast mass on general motor functioning has also been established, and it is important to keep that in mind when structuring kinesiological engagement of ski instructors, especially when evaluating their performance of demanding skiing techniques.

The obtained results represent a realistic illustration of the biomotor structure of ski instructors, who, due to their orientation towards the development of skiing and educational interventions, direct their kinesiological engagement primarily towards the improvement of skiing skills. Ultimately, complex and competitive skiing manifestations can be performed only with a high level of acquisition of specific techniques. Finally, it can be concluded that information obtained in the present research represents a kind of referent values for almost all populations in alpine skiing whose development forms have reached definite values or the final development phase. Such and similar research studies should be conducted, for the purpose of improving alpine skiing, on as large a sample of skiers as possible in order to determine the principles of biomotor functioning of different skiing populations more precisely.

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RELACIJE BIOMOTORIČKIH STRUKTURA I IZVEDBA TEHNIČKIH ELEMEATA ALPSKOG SKIJANJA HRVATSKIH UČITELJA SKIJANJA

SAŽETAK

S ciljem identifikacije faktora biomotoričkog statusa alpskih skijaša u predikciji njihovih specifičnih znanja, na uzorku od 79 kandidata za učitelje skijanja primijenjena su tri seta varijabli od ukupno 24 testa (9 varijabli za procjenu antropometrijskih karakteristika, 8 varijabli za procjenu motoričkih sposobnosti i 7 varijabli za procjenu specifičnih skijaških znanja alpskog skijanja). Nakon preliminarnih procedura obrade koje su obuhvaćale deskriptivne operacije i faktorizaciju svakog prostora zasebno, relacije između dobivenih latentnih dimenzija utvrđene su korelacijskom analizom. Ekstrahirani varimax faktori definirani su kako slijedi – u prostoru morfologije tri faktora: V1 – voluminoznost i transverzalna dimenzionalnost skeleta, V2 –longitudinalna dimenzionalnost skeleta, V3 – potkožno masno tkivo; u prostoru motorike 2 faktora: V1 – agilnost i eksplozivna snaga, V2 – statička snaga i ravnoteža; dok je u prostoru motoričkih znanja izoliran generalni faktor specifičnih motoričkih znanja alpskog skijanja. Dobivena je statistički značajna pozitivna korelacija agilnosti i eksplozivne snage s generalnim faktorom skijaških znanja pa su upravo agilnost i eksplozivna snaga temelj kvalitetne izvedbe naprednih i natjecateljskih tehnika u alpskom skijanju. Naime, pri realizaciji naprednih i natjecateljskih tehnika alpskog skijanja, koje podrazumijevaju visoku razinu usvojenosti skijaških znanja te posjedovanje potpune automatizacije pri izvedbi, sve radnje se vrše brzim i eksplozivnim promjenama pravca kretanja.