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A DIGITAL REVOLUTION IN RECREATIONAL AND COMPETITIVE SPORT, USING THE EXAMPLE OF THE DEVELOPMENT OF A YOUNG OLYMPIC SPORT, WALL CLIMBING

Theses of Doctoral Dissertation

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1. Introduction

The starting point for my research is the development of university sports, university extreme sports, the digitalisation of society and the rise in popularity of wall climbing. The role of sport and extreme sports among young people, young adults and students in higher education is unquestionable.

1.1 Reasons for my choice of topic

Nearly 30 years of experience in university sport, in the world of extreme sports, and in particular in climbing, provide me with the basis for research into the modernisation of the sport. The relevance of this research is confirmed by the following aspects:

- The world, including sport, is undergoing a massive digitalisation process
- Higher education and the sporting life in higher education are changing
- Extreme sports are popular
- Climbing has become an Olympic sport

The overarching, initial motivation for my research is: 'How does the digital transformation of the Clift smart climbing wall ecosystem affect sport, including university sport and the strengthening of the young Olympic sport in the Games programme?

1.2 The research model

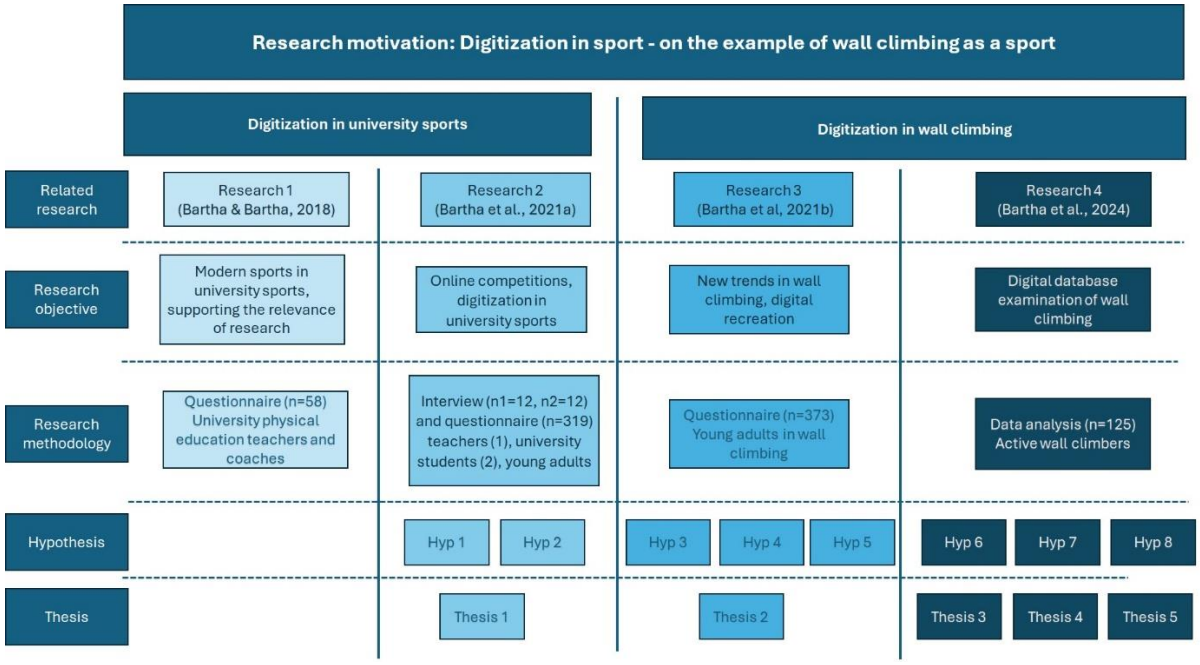

Figure 1. Research framework for a doctoral thesis

Source: own editing

2. Climbing as a sport under study

The focus of our research is on the digitisation of a young Olympic sport, the application of new sporting tools and technologies, and the creation of innovation for sport development.

Academic research (Bartha et al., 2024) has investigated wall climbing from a variety of perspectives, including athlete performance, physiological effects, and technical and tactical elements of the sport.

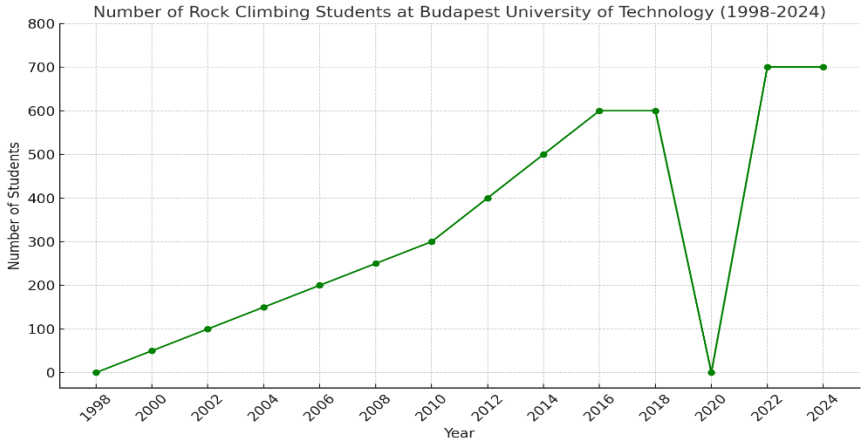

Figure 2. Trends in the number of masonry students at the BME (1998-2024)

Source: own editing

3. Clift Climbing

The Clift Climbing smart climbing wall ecosystem is a data-driven intelligent system that supports both recreational and competitive sports. It helps track training, plan routes, set challenges and games, analyse and store data, and use lighting.

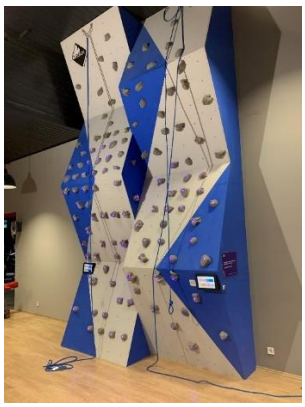

Figure 3. Smart climbing wall

Source: own editing

Figure 4. Smart grip with capacitive sensor

Source: own editing

4. Research Methodology

The aim of my research is to prove through data analysis that digitalisation and the smart climbing wall ecosystem is a data-driven intelligent system that supports both recreational and competitive sports. It supports training tracking, route planning, challenges, games, data analysis and storage, and route lighting.

4.1 Research hypotheses

The aim of my research is to demonstrate through data analysis that the digitalisation and smart climbing wall ecosystem is a data-driven, intelligent system that provides effective support for both recreational and competitive sport. In order to achieve this, the following hypotheses have been formulated, which are closely related to the questions that the research aims to answer.

H1 The Covid epidemic has discouraged generations Y and Z from taking part in sport, so young people are doing less.

H2 Knowledge/use of sports apps is not widespread among Generation Y and Z during the Covid epidemic.

H3 Young people are more digitally literate, actively use their IT devices and are partially familiar with sports-related apps and websites.

H4 Those who are familiar with sport-related applications are more likely to use these digital platforms.

H5 Those who are familiar with and use sport-related applications are more likely to require digital recording of their activities.

H6 There is a significant stochastic relationship between the variables used to examine wall climbing performance - gender, age, body weight, number of climbs, level of knowledge

H7 The medians and distributions of the scores of athletes grouped by gender and climbing skill level differ along certain variables.

The above hypotheses lay down the methodological basis for the research and provide a framework for the studies.

4.2 Methods and data

To ensure the thoroughness and reliability of the research, it is essential to develop an appropriate methodological framework and to systematically collect and analyse data.

In the embedded research entitled "Continuing education of trainers and teachers in sport in higher education: the present and future of modern sport" (Bartha and Bartha, 2018), I applied a quantitative method based on the use of questionnaires.

The analysis of my second research explored the data that guide the importance of online space in sport, and more specifically in university sport.

In my study, I used a mixed method. In the second phase of this research, quantitative data were used to compare time periods for two recreational sporting events (during the covid period), supplemented by a pre-covid event. Statistical methods used were two-sample t-test, independence test and cluster analysis. My hypotheses H1 and H2 are related to this research and were used to formulate Thesis 1 (Bartha et al., 2021)

In my research on people involved in the sport of wall climbing (athletes, coaches, trainers, trainers, operators), I used an online questionnaire and interviews, i.e. I based my conclusions on a combination of qualitative and quantitative techniques. I used SPSS to analyse and answer the hypotheses (H3, H4, H5). Statistical analysis was performed using cross tabulation and comparative analysis. An empirical analysis was also conducted using interviews with primary and secondary data (Bartha et al., 2021)

Finally, I conducted statistical analyses of the data generated by the Clift Climbing wall-climbing app involving n=125 people. In this part of my research, I used statistical methods such as correlation analysis between variables, non-parametric statistical tests and cluster analysis (Bartha et al., 2024).

5. Results

The data collected during the research and the results of the statistical analyses clearly show the different aspects of sport development and the impact of innovations aimed at improving athletes' performance. The following section presents the main findings that support the research hypotheses.

5.1 Introductory research results

Implementer research (Bartha and Bartha, 2018) is a research approach that focuses on the practical application of scientific theories and innovations, particularly in a particular setting or context.

5.2 Results of the analysis of online sporting events

The organisation of sport events on online platforms has brought unexpected success and results. (Ács et al., 2021)

The questionnaire was completed by 213 males and 107 females (n=320). The majority of respondents were aged between 18 and 25 years (n=239), but there were also respondents younger than 18 years (n=3), from the 25-40 age group (n=68) and over 40 years (n=10).

After analysing the answers to the questions, several cross-tabulations were made using IBM SPSS 23 software. The cross-tabulations examined the relationship between the variables in the questionnaire (gender, age, type of sport, knowledge of sports apps, use of apps). For gender and age of the respondents, gender and sport form, gender and knowledge of sport applications, age and sport form, age and knowledge of sport applications, the two variables are independent of each other and the association measures indicate independence.

Weak association relationships can be detected (Cramer's V, Khi squared) between respondents' gender and app users (Cramer's V=0.148; Khi squared=3.1), and between the type of sport and app users (Cramer's V=0.102; Khi squared=15.9), and cross-tabulation of sport format and app users (Cramer's V=0.139; Khi squared=1.6). There is a one-way and strong relationship between knowledge of sport-related mobile apps and their use, with a strong association measure (Cramer's V=0.555; Khi squared=0.0).

A comparative series of races between two online platforms was then analysed using a real-time, non-quarantine race. In the first event, 447 men and 203 women registered, for a total of 650 participants (71.2%).

For the second online competition, 316 men and 189 women entered, for a total of 505 (55.8%). Most of the online platforms used were popular applications known on the international market: Strava, Adidas, Endomondo, Nike+ Run Club. The race was accepted by covering a minimum distance of 5 km, registering and submitting. The average distance run in the first event was 5.62 km (standard deviation: 1.52 km) and in the second event: 5.83 km (standard deviation: 3.57 km). The number of registrations, both separately and in total, exceeds the number of participants in previous university running events during the infection-free period (Fun

Marathon 1 - BME race: registrants: 227; starters: 107; finishers: 101; and Fun Marathon 2 - BME race; registrants: 19; starters: 19; finishers: 19).

This was followed by an examination of the change in the amount of running. The solution in this case was a two-sample t-test (unpaired, all participants were considered). Let $\alpha = 5\%$ (0.05). The two-sample t-test: $t = 1.23$, $p = P(|t|<1.23) = 0.216$, $p > 0.05$, thus the alternative hypothesis is rejected and the null hypothesis is accepted. Running performance did not differ significantly between the two events.

5.3 Results of digital recreation

The respondents of our first questionnaire (n=373) were students and athletes climbing walls at the Sports Centre of the Budapest University of Technology and Economics, as well as from climbing centres in Budapest and, via the online questionnaire, from several university wall climbing centres - Szeged, Veszprém, Miskolc, Győr. Amateur and/or novice athletes made up the largest proportion of respondents. The other stakeholder groups, competitors, coaches and wall coaches, responded in overwhelmingly equal numbers.

	Frequency	**Percentage**	**Cumulative percentage**
Starter/Adult	321	86,1	86,1
Professional/Competitive	20	5,4	91,4
Operator/Manager	2	,5	92,0
Instructor	9	2,4	94,4
Interested	9	2,4	96,8
Other	12	3,2	100,0
Total	**373**	**100,0**	

Table 1. Distribution of respondents

Source: own calculation

The vast majority of respondents were in the 18-25 age group, with 73.5 percent of them. This is not surprising as the first survey was conducted at the BME Sports Centre. The presence of the 25-40 age group was also high, with 18.2 per cent of the respondents aged 25-40.

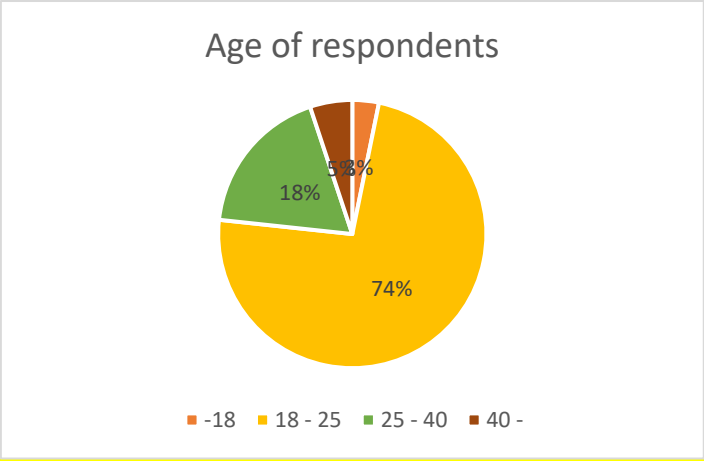

Figure 5. Classification of subjects by age group

Source: own calculation

Of the athletes included in the dataset, 69.2 per cent were familiar with a sports-related mobile app, while 30.6 per cent had not encountered one. The number of respondents who are familiar with a mobile app is very high, which is not surprising as more than 90 percent of the respondents are in the 18-40 age group. The question is, why is the proportion of people not familiar with the app relatively so high? To answer this hypothesis, we look at the cross-tabulation between age and app familiarity. The results are presented in Table 2.

		Do you know any sport-related mobile apps?			Total
		yes	no	no answer	
Age group	-18	7	5	0	12
	18-25	**181**	**92**	1	274
	25-40	**57**	**11**	0	68
	40-	13	6	0	19
Total		258	114	1	373

Table 2. Cross-tabulation of age and knowledge of the app

Source: own calculation

The relationship between the two variables is considered weak rather than medium according to the contingency coefficient, which has a value of 0.153 and a significance level of 15.7 percent. This value is considered less acceptable. Roughly one third of 18-25 year olds do not use a sports-related app. Our explanation for this result is that amateur, recreational sportsmen and women do not necessarily need to use additional digital support for more than one sport, or

that there is no support tool in the sport - in this case wall climbing - that would help them to do the activity more interestingly.

Of the nearly 400 respondents, 51.7% have never used an app to support their sporting activities. However, 39.7% of respondents are aware of and have used apps. It can be said that further socio-economic development and learning is needed in the sports world to change attitudes towards digital support for sporting activities as a positive outcome. Before answering the further question, we made another cross-tabulation to analyse whether those who know such an app have ever used it?

The contingency coefficient shows a strong relationship between the two questions, with a value of 0.517. This value is significant at less than one thousandth of a power level, and together with other indicators of this type, such as the Phi and Cramer V indicators, it also shows a significant relationship between the variables. The cross-tabulation of the questions is shown in Table 3.

		Do you know any sports-related mobile apps?			**Total**
		yes	**no**	**no answer**	
If you are familiar with such an app, have you used it before for sports?	**Yes**	146	2	0	**148**
	No	109	84	0	**193**
	No answer	3	28	1	**32**
Total		**258**	**114**	**1**	**373**

Table 3. Cross-tabulation between those who know and use a sports mobile app in sport

Source: own calculation

Three quarters of respondents would like to see data on climbing recorded. Hobbyists do not consider this necessary. This activity will help the development of the athletes and the sport, and the possibility of scientific studies. Our expectation of the cross-tabulation needed to answer this question is summarised in Table 4.

		If you have climbed a wall before and are active in the sport, would you find it useful to record and describe the data and values of your climbing?			Total
		yes	no	no answer	
If you are familiar with such an application, have you used it for sports?	Yes	115	28	5	**148**
	No	145	40	8	**193**
	No answer	21	3	8	**32**
Total		**281**	**71**	**21**	

Table 4. Mobile app users' and climbers' need to record their data

Source: own calculation

The relationship between the two variables is very weakly medium with a contingency coefficient of 0.254. This indicator is also significant. The explanatory power of the coefficient of contingency is weakened by the fact that the majority of respondents, although they have never used a mobile application, would like to record their data in this sport. However, the value of the contingency coefficient does not allow us to reject the conclusion that active wall climbers do not require the recording of their data. The results so far have confirmed our idea that improvement and digitisation is essential, and further technical literature research and investigation has resulted in the compilation of a smart climbing wall that answers a number of additional questions.

5.4 Clift data information analysis

Five statistical variables, or measures, were used to examine the performance of the climbers (Bartha et al., 2024): gender (male, female), age (year), body weight (kilograms), skill level (novice, intermediate and advanced), number of climbs.

The interpretation of the five variables is as follows: two are nominal and ordinal variables (gender and knowledge level), the other three (age, body weight and number of climbs) are metric statistical variables measured on a ratio scale. The linear stochastic relationship between the three metric variables, i.e. age, body weight and number of climbs, is represented by Pearson's correlation we can calculate. From Table 5 it is clear that the correlation between the number of climbs and the other two variables is not significant. This leads us to conclude that there is no linear relationship between the two variables. However, there is a positive, weakly moderate linear relationship between age and body weight, which is also significant. It can be concluded that as age increases, body weight changes, fewer climbs are made and the time spent climbing slows down. while the measure of the number of years per square metre was used between the categorical and metric variables.

Statistical variables		Body weight, kg	Number of climbs
Age, year	Pearson	**,388****	**-0,045**
	2-sided sign.	0	0,616
	N	125	125
Body weight, kg	Pearson		**0,105**
	2-sided sign.		0,244
	N		125

Table 5. Stochastic relationship between metric variables

Source: own calculation

The Cramer association measure V between the age and knowledge level of athletes takes a value of 0.116, which is considered very weak, and the corresponding chi-square value, i.e. the significance of the measure, is 0.430, thus confirming the independence between the two categorical variables. Finally, the association measures between the categorical and metric variables are compared. For this purpose, we use the étanium square measure. We do not take into account the difference in the eta-squared according to which one is considered independent, but automatically analyse only the larger measure with the associated chi-squared as the significance level. Our results are reported in Table 6.

Eta squared			
		Gender	**Knowledge level**
Age	Éta-négyzet	**0,311**	**0,288**
	Szign. (2-old.)	0,739	0,925
	N	125	125
Body weight, kg	Éta-négyzet	**0,86**	**0,58**
	Szign. (2-old.)	<0,001	0,468
	N	125	125
Number of climbs	Éta-négyzet	**0,41**	**0,589**
	Szign. (2-old.)	0,826	0,157
	N	125	125

Table 6. Association relationship between metric and categorical variables

Source: own calculation

Of the five variables, only body weight and gender showed a strong and significant relationship, with an eta-squared value of 0.860 and a chi-squared value of less than 0.001. This suggests that the body weight of men is significantly different from that of women. In addition, there is a stronger association between the number of climbs and the level of knowledge, with a value of 0.589 and a chi-square value of 0.157. The analysis shows that this chi-square value is relatively high, but much lower than the other significance levels. This suggests that athletes with a higher skill level are more likely to use the climbing wall more often and to train more. The other relationships can be considered independent. This concludes the analysis of the relationships between the variables.

Do the averages of our metric variables by categorical variable match?

In the case of the classic one-factor ANOVA analysis, the test met the required criteria. To test for identity between group means, we look at the two categorical variables as grouping factors and the means of the three metric variables. In this way, six analyses are performed, but first the three conditions for the three metric variables must be examined. First, we list the relationships where the means of the metric variables according to the categorical variables are equal. We first examine gender identity, but for the median instead of the mean. It is expected that similar results would be obtained for the mean, so this is omitted.

The results show that the medians and distributions of the gender groups are the same for age. However, the medians and distributions for body mass and number of climbs are significantly different. This can be interpreted as meaning that the age tree by sex is not different, i.e. the sex of the athlete is not a discriminating trait.

However, the medians and distributions of body mass and number of climbs differ by gender. This means that the body mass of a female and a male athlete differs and the number of climbs differs by gender. SPSS 26 tables of the results are summarised in Table 7. In Table 8, the medians by skill level and their distribution are examined. The table shows that the medians and their distributions do not differ by metric variable. This also means that the age, body weight and number of climbs of the athletes are not significantly different according to the three knowledge levels. Of these, the identity between knowledge level and number of climbs is perhaps the most surprising, as one would expect athletes with higher knowledge to climb more.

Testing the results of hypotheses				
	Null hypothesis	**Test**	**Sign.[a,b]**	**Decision**
1	The medians of age are the same by gender category..	Independent sample median test	,823	We retain the null hypothesis.
2	The distributions of age are identical by gender category.	Independent samples Kruskal-Wallis test	0,536	We retain the null hypothesis.
3	Medians of body weight are identical by gender category.	Independent samples median test	<.001[c]	We reject the null hypothesis.
4	The distributions of body mass are identical by gender category.	Independent samples Kruskal-Wallis test	0	We reject the null hypothesis.
5	The medians of the numbers of climbs are identical by gender category.	Independent samples median test	,006[c]	We reject the null hypothesis.
6	The distributions of the numbers of climbs are identical by gender category.	Independent samples Kruskal-Wallis test	0,001	We reject the null hypothesis.

a. The significance level is 0.050.

b. We see asymptotic significance.

c. Yates continuity corrected asymptotic significance.

*** Correlation is significant at the 0.001 level.*

Table 7. Results of the Kruskal-Wallis ANOVA test for the categorical variable "NO"*

Source: own calculation

	Null hypothesis	Test	Sign.[a,b]	Decision
1	The medians of age are identical by gender category.	Independent samples median test	0,614	We retain the null hypothesis.
2	Age distributions are identical by gender category.	Independent samples Kruskal-Wallis test	0,806	We retain the null hypothesis.
3	Medians of body weight are identical by gender category.	Independent samples median test	0,383	We retain the null hypothesis.
4	The distributions of body weight are identical by gender category.	Independent samples Kruskal-Wallis test	0,402	We retain the null hypothesis.
5	Medians of the number of climbs are identical by gender category.	Independent samples median test	0,851	We retain the null hypothesis.
6	The distributions of the numbers of climbs are identical by gender category.	Independent samples Kruskal-Wallis test	0,402	We retain the null hypothesis.

a. The significance level is 0.050.
b. We see asymptotic significance.
c. Yates continuity corrected asymptotic significance.
*** Correlation is significant at the 0.001 level.*

Table 8. Results of the Kruskal-Wallis ANOVA test for the categorical variable "LEVEL OF KNOWLEDGE"*

Source: own calculation

How many latent variables can be used to express the five variables we are studying?

Since not all of the five variables are metric variables, we cannot use the classical principal component analysis method to transform the number of variables into latent variables. The obstacle to this is that classical principal component analysis accounts for the variance and correlation between variables. However, categorical variables do not have means and variances, so correlation between them cannot be calculated. Multivariate statistics, however, offers a way to overcome this problem. Nominal and ordinal variables are collectively referred to in the literature as categorical variables, and principal component analysis including such variables is called categorical principal component analysis, and thus falls under the heading of optimal scaling. SPSS allows you to count components on data sets with such a scale in the Optimal Scaling tab. Categorical principal component analysis gives very similar outputs to classical principal component analysis. The output tables of categorical principal component analysis are described below.

Summary of the model			
Principal components	**Cronbach-alfa**	**Variance value**	
		Eigenvalue	**% of variance**
1	0,597	1,913	38,265
2	0,178	1,166	23,325
3	-0,035	0,973	19,459
Total	**0,942[a]**	**4,052**	**81,049**
a. Cronbach's alpha based on total equity.			

Table 9. Variances of the components of the categorical principal component analysis

Source: own calculation

Table 9 shows that the number of principal components of the chosen model is three. This is chosen because it gives 81.049% of the variance. If we had chosen two components, this would only have given 61.590% of the variance, which is below the recommended 66% - a thumbnail in the literature. The Cronbach's alpha values are very low. In our case, this suggests a less appropriate model, although it falls just short of the recommended value of 0.6 with a result of 0.597.

How can athletes be grouped according to their performance and can the groups be explained?

Using cluster analysis, I am looking for answers to the question of how wall climbers can be divided into groups, i.e. whether there are homogeneous groups of people with similar characteristics within the sport. For the analysis I used the K-means clustering procedure offered by SPSS 26. In the procedure, I performed five clusterings, starting from two and finally selecting six clusters. I chose the model with four clusters because this variant separates the athletes appropriately. The first clustering was performed with the available raw data, and then the data measured on the three metric scales were normalized by their standard deviations to filter out differences in the magnitude of the variables.

Clusters	Number of cases	
	with standard data	with standard deviation
1.	29	20
2.	9	69
3.	38	11
4.	49	25
Total	125	125

Table 10. Number of climbers in each cluster

Source: own calculation

The results resulted in three larger homogeneous groups (clusters 1, 3 and 4) and one smaller group (cluster 2) formed by the clustering procedure. The latter two wall-climbing clusters can be considered outstanding along some variable.

6. Theses

Below, I summarize in the form of theses the most important findings of the empirical research that forms the basis of the doctoral research, in the form of new scientific results.

THESIS 1 (related hypotheses: H1 and H2): Based on the study conducted among Generation Y and Z, no significant association can be demonstrated between gender and age, gender and sport form, gender and knowledge of sports application, age and form of sport, and between age and knowledge of sports applications, i.e. these categorical variables are independent of each other at a 5% significance level, but at the same time, a weak association can be shown between the form of sports and the knowledge of applications, as well as between the form of sports and the use of applications at the same significance level.

THESIS 2 (related hypotheses: H3, H4, H5): The use of sports applications does not depend on the age of the athlete, but those who are familiar with sports applications are more likely to use them and require the recording of data (and presumably their analysis) There is no relationship between age and knowledge of the sports application significant association relationship at 5% significance level. A significant association can be detected between the knowledge and use of the applications at a 5% significance level, and the same is true for the relationship between those who use the application and those who request to record their sports activities, also at a 5% significance level.

THESIS 3 (related hypothesis H6): In the case of the 5 variables (gender, age, body weight, number of climbs and knowledge level) used to examine wall climbing performance, based on pairwise correlation analyzes (α=5%), a positive, weakly moderate relationship between age and body weight can be shown who (body weight seems to increase with advancing age); a strong significant relationship can be shown between body weight and gender; the relationship between the other variables can be considered independent.

THESIS 4 (related hypothesis H7): On the basis of the examination of the groups of climbing athletes included in the study, who were trained according to gender and skill level as categorical variables, it can be concluded that the medians of the groups trained according to gender are the same in terms of age, but at the same time, the medians and distributions of body weight and the number of climbs are significantly different (α=5%); examining the medians and distributions of the groups trained according to the level of knowledge, no significant differences can be found according to the quantitative variables, i.e. age, body weight and number of climbs.

7. Summary

Research conducted among the 18-25-year-old age group shows that young people are increasingly active in sports, although digital platforms and applications are only partially used to monitor their sports activities.

The data generated by smart climbing walls such as Clift Climbing and the positive feedback associated with them confirm the need for further research. The importance of data recording, confirmed by those actively involved in wall climbing, suggests that athletes are increasingly recognizing the role of technology in improving their performance.

7.1 Further directions of research

The Clift Climbing platform, presented at cliftclimbing.com, is an innovative digital tool that has revolutionized data collection, performance analysis and athlete skill development in the climbing world.

Further research directions: data-driven performance development, expansion of rehabilitation and preventive opportunities, strengthening of the community and competitive spirit, and expansion of the business model and market applications.

The Clift Climbing platform has brought significant innovations - novum - to the world of wall climbing, but there are many additional research directions and innovation opportunities available through which the platform can be further developed.

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