Athens Journal of Sports

Quarterly Academic Periodical,
Volume 11, Issue 3, September 2024
URL: https://www.athensjournals.gr/ajspo
Email: journals@atiner.gr
e-ISSN: 2241-7915 DOI: 10.30958/ajspo

Athens Journal of Sports

Published by the Athens Institute for Education and Research (ATINER)

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The ***Athens Journal of Sports (AJSPO)*** is an Open Access quarterly double-blind peer reviewed journal and considers papers from all areas of sports and related sciences. Many of the papers published in this journal have been presented at the various conferences sponsored by the Sport, Exercise, & Kinesiology Unit of the **Athens Institute for Education and Research (ATINER)** & the Panhellenic Association of Sports Economists and Managers (PASEM). All papers are subject to ATINER's Publication Ethical Policy and Statement.

The Athens Journal of Sports

ISSN NUMBER: 2241-7915 - DOI: 10.30958/ajspo

Volume 11, Issue 3, September 2024

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The current issue is the third of the eleventh volume of the *Athens Journal of Sports*, published by the Sport, Exercise, & Kinesiology Unit of the ATINER under the aegis of the Panhellenic Association of Sports Economists and Managers (PASEM).

Gregory T. Papanikos, President, ATINER.

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- Acceptance of Abstract: 4 Weeks after Submission
- Submission of Paper: **14 April 2025**

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- Submission of Paper: **1 July 2024**

Academic Member Responsible for the Conference

Dr. Maria Konstantaki, Academic Member, ATINER & Senior Lecturer, Buckinghamshire New University, UK.

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Development of Loan Players in Professional Football

By Niklas Günter[*] & Lars Vischer[±]

This study analyses the development of loan players in the German Bundesliga from 2010/2011 to 2021/2022, motivated by the increasing importance of player loans in professional football and upcoming FIFA rule changes to reduce loans. The study analyses 378 loan transfers and compares them with 6,162 non-loan players. The focus is on the three main protagonists: the loaned player, the lending club and the loaning club. It is found that loan players do not receive more playing minutes than average Bundesliga players and that there is no recognisable increase in the market value for the loaning club, which does not improve the negotiating position when selling players. In our data, the loaning club also does not benefit significantly from the sporting performances of the loaned players.

Keywords: *Bundesliga, development, football, loan player, market value*

Introduction

From 1 July 2024, FIFA limits loan periods and the number of loan players further (Sportschau 2022). Why does FIFA want this rule change? In order to promote the development of football players, the player loan option has become an increasingly important strategic practice for football clubs in recent decades. Either the player's sporting development is promoted and the releasing club subsequently benefits in sporting terms or the player's market value increases as a result of such development and the releasing club benefits financially. According to FIFA, the development of young players and sporting balance should be promoted and hoarding by clubs prevented. Several top European clubs rely heavily on the loaning of players as a business model. According to Chelsea FC, it has 24 professionals under contract in 2022 who are currently on loan to other clubs (Sportschau 2022).

When analysing player loans in professional football, some research focuses on the accounting of loan players (e.g., Madeja 2007 and Weber 2016). Kent et al. (2022) provide a sports psychology perspective on player loans. Müller (2015) states that the effort level of loan players is reduced after the loan contract expires. Carmichael et al. (1999) analyse which attributes of football players have a particular influence on their transfers and possible transfer fees and also look at the labour market for loan players. Furthermore, numerous other reasons for player loans can be identified at club level (e.g., Bond et al. 2010 and Berkemeyer 2011). In the best-case scenario, the player loan is not only intended to help the player develop athletically but also to increase his market value so that the releasing club can sell him if necessary. However, does a loan really achieve this desired result,

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and what would be the decisive factors for this? We therefore want to investigate how market value actually develops from an economic perspective using the Bundesliga as an example, thereby supplementing existing research and identifying factors that are the main drivers for loans. Therefore, the research question of this paper is:

How is the development of loan players in the Bundesliga progressing?

To answer this question, we analyse a total of 378 loan transfers from the 2010/2011 to 2021/2022 Bundesliga seasons in Germany's top division. These are twelve consecutive seasons. We consider players who have been loaned out by Bundesliga clubs to be able to assess the same level in the league.

Conceptual Framework

Legal Background

To properly understand the phenomenon of player loans, the legal basis of loan agreements in professional football should first be explained. Player loans in professional football are subject to legal principles that include both international and national regulations. Internationally, the FIFA regulations (FIFA 2022) apply, nationally those of the DFB and its subsidiary DFL. The DFL regulates player loans in the 1st and 2nd Bundesliga in accordance with the "Player Licence Regulations" (DFL 2021). A loan agreement requires the consent of the lending club, the borrowing club and the player. The summer transfer period runs from 1 July to 31 August and the winter transfer period from 1 January to 31 January. Changes require the approval of the DFB and FIFA. Players remain tied to the lending club after the end of the loan period. The DFL has no specific loan regulations but refers to the rules for permanent player transfers. Since the 2022/23 Bundesliga season, FIFA has adapted the regulations, limiting loans to a maximum of one season and restricting the number of loan players permitted per club per season. Loan contracts can contain certain additional options. An extension option allows the loaning club to extend the loan after it expires. Some contracts also include a purchase option that allows the loaning club to sign the player permanently by paying a predetermined transfer fee. This option allows the loaning club to test the player's sporting ability before deciding whether to sign him permanently (Weber 2016). In February 2019, the 18 first-division clubs had a total of 552 licensed players under contract, which corresponds to an average of 30.67 licensed players per club. A total of 40 players were loaned out in the 2018/2019 season, with three loans being cancelled in the winter transfer window. The remaining 37 loan players therefore accounted for around 6.7 % of the 552 licensed players in the first Bundesliga (DFL 2019).

Player transfers have an increasing impact on the balance sheet of a club (Ludwigs 2022) and are important assets widening the financial room for manoeuvre of clubs. Transfers also affect accounting regulations (Sirakaya 2023).

Neumeister (2004), Madeja (2007) and Weber (2016) also deal with the accounting of players. Labour law perspectives on temporary work are also dealt with based on player loans (Brömmekamp 1988, Bohnhaus 2003 and Berkemeyer 2011).

Reasons for Player Loans

The reasons for player loans are manifold and before the legal aspects are presented, various perspectives on the topic are discussed. When looking at the performance behaviour of loan players in professional football, it was found that the loan players observed were indeed more motivated than permanent players. The increased effort level of the loan players decreased again after the loan contract expired (Müller 2015). Furthermore, a sports psychology perspective can be taken on player loans, which looks at the effects of the loan on the personal well-being and stress levels of professional footballers (Kent et al. 2022). In principle, professional footballers are usually loaned out to clubs that are weaker than the lending club in sporting and economic terms with the justification of the player's increased chance of better playing time (Carmichael et al. 1999). The network characteristics of the loan system in European football must also be taken into account. The loan system in the European leagues is closely interconnected, which benefits some elite clubs in particular (Bond et al. 2020). This may have prompted FIFA to tighten the regulation of loan deals. Loan deals within the framework of collaborations between clubs are also relevant in this context (Backhaus 2022).

The development of the loaned players can only be properly assessed if the different objectives of a loan are known. As both clubs involved in the process and the player himself must agree to a player loan, the exemplary motives of these three protagonists are analysed in turn. On the part of the loaning club, there are various reasons for deciding to loan a player. Firstly, the costs for the loaning club for a player loan are significantly lower than for the permanent signing of a player. Football clubs have no economic interest in allowing a player to move to another club on a free transfer at the end of his contract, they usually aim to either extend the contract early or sell the player for the highest possible transfer fee. A loan offers the loaning club cost advantages over a permanent contract in that no transfer fee has to be paid for the player (Müller 2015) as the transfer rights to the player remain with the lending club (Berkemeyer 2011). A loan fee may be required for the loaned player; however, it is typically significantly lower than the transfer fee for a permanent player (Müller 2015). These cost advantages mean that financially weaker clubs in particular hope to be able to loan out strong footballers for whom a permanent signing would not have been financially viable. In this way, these clubs hope to be able to put together a team that remains competitive (Weber 2016). A player loan also offers a club the opportunity to test the quality of a player before deciding whether or not to sign him permanently. This is possible if the loan agreement includes the option to sign the player permanently in the form of a purchase option. This minimises the risk of a player not delivering the desired performance after signing on permanently such that the high transfer fee is not economically viable. Another reason for loaning out a player is the possibility of temporarily replacing a regular player if he is absent due to injury. Particularly in the case of long-term injuries, the playing quality of the reserve players in the squad is often not sufficient to adequately replace the injured player. In this case, a loan player can act as a replacement for this period of time (Berkemeyer 2011).

The motives of the lending club for agreeing to a loan differ from the motives of the loaning club. In the case of young players in particular, the club often has an interest in loaning them out for training purposes (Berkemeyer 2011). With the help of a loan, a player who is currently not needed should gain the necessary match practice outside his own club and prove his suitability for the league. In the best-case scenario, the loaned player can improve his sporting quality during the loan period thanks to the experience gained and gain more playing time when he returns to his home club (Weber 2016). Financially well-positioned clubs in particular deliberately retain many young talents and use the opportunity of a loan to specifically train players (Berkemeyer 2011). Another reason for loaning out players is to reduce the club's personnel costs. This motive arises in particular when dealing with players who foreseeably will not be used frequently in a season. If a player is loaned out, his salary costs are usually borne in full by the loaning club, which sometimes even has to pay a loan fee to the loaning club (Berkemeyer 2011). A player can also terminate his existing contract with a club without notice following the DFL's LOS (2023) if he makes fewer than four competitive appearances in a season if there are no special circumstances, a loan gives the club the opportunity to prevent a player who is currently not needed but has long-term prospects from leaving on a free transfer (Weber 2016). Increasing the internationalisation of the football team could also be an option. Following the Bosman ruling in 1995 and the subsequent free movement of footballers, professional football clubs are increasingly utilising foreign players, which has been proven in the Greek league for regular players, for example (Papanikos 2024).

Finally, the player's reasons for signing a loan deal should also be considered. It is in the player's interest to get regular match appearances to maintain and ideally improve his performance. This interest is independent of the player's age and experience (Berkemeyer 2011). By performing well during the loan period, the player wants to increase his market value and at the same time offer himself more playing time at his home club (or another club) and thus also have a better negotiating position for future contracts (Weber 2016). The impetus for negotiations regarding the conclusion of a loan therefore often comes from the player himself if he realises that he rarely gets to play for his current club. Especially before major international tournaments, players with national team ambitions see a loan as an opportunity to prove their ability to increase their chances of being nominated for a squad by the national association (Berkemeyer 2011). The increased level of effort already mentioned also plays a role here (Müller 2015).

Hypothesis Development

With the help of the conceptual background and our considerations, five overarching hypotheses are formulated. The aim is to analyse the development of loan players.

Firstly, there is the club that lends a player and thus relinquishes him from a sporting perspective for a certain period is hoping for a positive development of this player. In the case of a sale, the club financially profits from this development as a sporting development would be reflected in an increased market value.

H1: The transferring club benefits financially from the loan of its player.

Furthermore, the receiving club hopes that the loan of the player will help it in sporting terms. This means that the loan player is either a favourable alternative for established players or possibly even a better performer. This is in line with the point that poorer clubs in particular loan out players for match practice from better clubs and therefore the loan players should be better than the average player in the squad of the receiving clubs.

H2: The loan player helps the receiving club in sporting terms.

For the transferring club, it is also interesting to know what the drivers are for the market value development of a loaned player. It is expected that the sporting performance is most important.

H3: Sporting performance is the main driver for the market value development of a loan player.

The player on loan is hoping above all for playing time to develop in such a way that he will be in a better position both sportily and financially in any subsequent contract negotiations after the end of his loan.

H4: Loan players get more playing time than established players.

There are differences between loan players and players who are not on loan. As an example, loan players are primarily young players. This leads to our final hypothesis:

H5: Loan players are younger than established players.

Data

A total of 378 loan transfers from the Bundesliga seasons 2010/2011 to 2021/2022 in the top German division are identified. Only those players who were loaned out by Bundesliga clubs to other Bundesliga clubs were included in the database. The focus on loaned players inside the first Bundesliga is intended to increase the comparability of player loans as their participation in the same competition can ensure similar framework conditions. The loan transfers analysed explicitly include player loans that were newly concluded in the twelve Bundesliga seasons examined. This means that a loan that began during the 2021/2022 season and ended after the end of the 2022/2023 season is included in the data basis while a player loan that began in the 2009/2010 season and continued in the 2010/2011 season was not included in the analyses. This focus on the start of the loan is based on the fact that player loans can be for up to two Bundesliga seasons and this structure can prevent duplicate listings of players. Overall, we consider the following number of loan players across the seasons: 26 (2010/2011), 28 (2011/2012), 33 (2012/2013), 30 (2013/2014), 24 (2014/2015), 24 (2015/2016), 27 (2016/2017), 28 (2017/2018), 36 (2018/2019), 46 (2019/2020), 47 (2020/2021) and 29 (2021/2022).

The data on player loans was generated via the transfermarkt.de website, which is operated by Transfermarkt GmbH & Co. KG, which in turn is majority-owned by the Axel Springer SE publishing group (Lanzolla/Giudici 2017). The player market value ratings from transfermarkt.de are considered particularly influential key figures in sports economics and are used in numerous empirical studies. Some football clubs use the market values as key figures in their annual financial statements, while players use their market value data in contract negotiations (Ackermann/Follert 2018). The market values on transfermarkt.de are based on a principle that the US journalist James Surowiecki refers to as the "wisdom of crowds". According to his reasoning, the accumulation of information from individual group members often leads to better group decisions than the approaches of individual participants and even experts. Misjudgements are supposed to be compensated for by the mass of assessments (Surowiecki 2005). A very high correlation has already been established between the market values estimated by transfermarkt.de and the actual transfer sums achieved, which legitimises the market value estimates of transfermarkt.de for further investigation (Gerhards et al. 2014). While most of the data on player loans comes from transfermarkt.de, the player performance data was generated by the established internet platform of the news magazine kicker (kicker.de, see Dilger/Vischer 2022) and other performance variables come from the platform footystats.org (see Shahriar et al. 2019).

A total of 38 loan transfers in the data set were cancelled before the originally agreed end of the loan period. However, the loans analysed here all exceed the duration of one half-series specified for this project and the reasons for loan cancellations are not considered due to the unclear data situation. For the 38 loans that lasted longer than one season, only the first season was considered, as otherwise, players in the same loan transfer would appear as two observations. In the case of six-month loans, only performance data from the respective half-season was considered.

Results

Sample Loan Player

Firstly, the loan players are analysed in isolation. To this end, various player characteristics and performance variables are reported. Grades are used to assess the performance of a loan player. While performance ratings of football players are published by various sports portals, the ratings from kicker.de are considered particularly relevant by the sports-interested public (Beils 2023). The average grades of the players in the season and the team in the respective season are considered here. The market values were collected by transfermarkt.de at the start and end of each loan period. The age variable refers to the start of the respective season.

As can be seen in Table 1, a total of 15 goalkeepers, 105 defenders, 130 midfielders and 118 forwards are among the players on loan. A total of 91 players were signed permanently by the receiving club, 110 returned to their home club, 65 were sold to another third club, 7 had their loan extended and 96 were loaned out again to another club. 191 players already had experience in the Bundesliga before going on loan, 101 are German nationals and 181 come from other European countries.

A one-sample t-test (95 %) was carried out for the variable's market value development and difference in grades. The null hypothesis in each case was ≤ 0. The positive market value development of players (Mean = 0.39, SD = 5.9) is not significant above a value of 0 with t (368) = 1.26 and p = 0.1038 and therefore the null hypothesis cannot be rejected. The difference in grades (Mean = 0.23, SD = 0.46) is significant above a value of 0 with t (339) = 9.23 and p = 0.0000*** and the null hypothesis can therefore be rejected. Here, the average grade of the loaned players (3.83) is worse than the average grade of the loaning team (3.60).

Table 1. *Descriptive Statistics on the Loan Player Sample*

	Mean	**SD**	**Min**	**Max**
age player	23.00	3.24	17.00	36.00
Goalkeeper	0.04	0.20	0.00	1.00
Defender	0.28	0.45	0.00	1.00
Midfielder	0.34	0.48	0.00	1.00
Forward	0.31	0.46	0.00	1.00
minutes_played_overall	1006.75	756.46	0.00	3060.00
appearances_overall	15.82	9.18	0.00	34.00
goals_overall	1.69	2.64	0.00	18.00
Grade_player	3.83	0.55	0.00	5.67
Grade_team	3.60	0.24	2.94	4.35
Grade_diff	0.23	0.46	-1.21	1.76
MV_begin	5.16	7.56	0.00	90.00
MV_end	5.55	8.04	0.10	60.00
MV_development	0.39	5.90	-34.00	58.00
N	378			

N = Sample Size, SD = Standard Deviation, Min = Minimum, Max = Maximum, MV = Market Value.

In Table 2, three models were calculated using linear regressions, with the dependent variable being MV_development. Additional control variables have been added to these three models to determine what influences the market value development of loan players. The sample was reduced to a total of 336 players because not all players had enough playing time to receive an average score or any score at all from kicker.de, for example. What is striking here is that the players' grades, goals scored and minutes played appear to have the greatest impact on market value development. As expected, age also plays a role in the development of the market value. The player's position, previous Bundesliga experience and the player's origin have no significant influence.

Table 2. *Linear Regression with MV_Development as Dependent Variable*

	(1)	**(2)**	**(3)**
Note_player	-2.019**	-1.910**	-1.864**
	(0.005)	(0.007)	(0.009)
minutes_played_overall	0.00204	0.00247*	0.00235*
	(0.057)	(0.038)	(0.049)
appearances_overall	-0.140	-0.174	-0.159
	(0.131)	(0.080)	(0.114)
goals_overall	0.482***	0.521***	0.499**
	(0.001)	(0.001)	(0.001)
age_player		-0.517***	-0.478***
		(0.000)	(0.000)
Position		-0.0753	-0.0757
		(0.876)	(0.876)
bundesligaexperience01			-0.859
			(0.198)
european1			0.671
			(0.375)
_cons	7.510*	19.33***	18.12***
	(0.011)	(0.000)	(0.000)
N	336	336	336
F	10.84	12.38	9.558
R^2	0.116	0.184	0.190

*p-values in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.*

Sample All Players

Table 3 uses a t-test to identify differences between players who are on loan and players who are in a normal employment relationship with their club. The variable MV_development cannot be analysed further, as this explicitly refers to the start of the loan period and the corresponding equivalent does not exist for regular players.

Overall, around 6 % of the players in the period under review were on loan. In Table 3, it is noticeable that there is a difference in age between loan players and non-loan players and loan players are younger on average. Furthermore, loan players play fewer minutes on average over the entire season than regular players in the teams. In terms of positions, it is noticeable that significantly fewer goalkeepers are loan players and that mainly attackers are signed as loan players.

Table 3. *Analysis of Players On and Off Loan*

	Loan Player	N	Mean	SD	t-test
minutes_played_overall	0	6,162	1116.407	975.804	109.7*
	1	368	1006.75	756.459	(2.12)
appearances_overall	0	6,162	15.864	11.615	0.0442
	1	368	15.820	9.177	(0.07)
goals_overall	0	6,162	1.621	3.256	-0.0717
	1	368	1.692	2.636	(-0.41)
assists_overall	0	6,162	1.183	2.093	0.101
	1	368	1.089	1.829	(0.91)
yellow_cards_overall	0	6,162	2.126	2.472	-0.000973
	1	368	2.127	2.222	(-0.01)
red_cards_overall	0	6,162	0.089	0.308	0.0109
	1	368	0.078	0.269	(0.66)
age_player	0	6,162	24.445	4.412	1.449***
	1	368	22.997	3.241	(6.20)
Goalkeeper	0	6,162	0.115	0.319	0.0755***
	1	378	0.039	0.195	(4.55)
Defender	0	6,162	0.314	0.464	0.0362
	1	378	0.277	0.448	(1.48)
Midfielder	0	6,162	0.375	0.484	0.0311
	1	378	0.343	0.475	(1.21)
Forward	0	6,162	0.195	0.396	-0.116***
	1	378	0.312	0.463	(-5.48)

*t-statistics in parentheses * p<0.05, ** p<0.01, *** p<0.001. Loan Player: 0 = no loan player / 1 = loan player, SD = standard deviation.*

Discussion, Implications, Limitations and Further Research

From 1 July 2024, FIFA wants to limit loan periods and the number of players further (Sportschau 2022). The following research question was therefore formulated at the beginning of this study: *How is the development of loan players in the Bundesliga progressing?* To investigate the research question empirically, five hypotheses were formulated to help answer the overarching question.

H1: The transferring club benefits financially from the loan of its player.

The lending club waves the loan player for a certain period and is hoping for a certain development of this player. In the case of a sale after the loan, this development is primarily monetary. Even without a sale, if the sporting development increases this would be reflected in the market value development and therefore an increase in the market value would be hoped for. It can be stated here that 156 players were sold to the loaning club or a third club at the end of the loan period. 110 players returned to their home club and 103 players were loaned out again. The mean values for the start and end of the loan as well as the development variable in Table 1 indicate that the market value is increasing, but not at a statistically significant level.

H2: The loan player helps the receiving club in sporting terms.

Furthermore, the receiving club hopes that the loan of the player will help it in sporting terms because the loan player is either a favourable alternative for established players or possibly even a serious performer. This is in line with the fact that poorer clubs in particular loan out players for match practice from better clubs and therefore the loan players should be better than the average player in the squad of the receiving club. A statistically significant difference can be observed between the average rating of the loan player and the average rating of the team. However, on average loan players are rated lower than the average player in the respective team. Of course, this does not rule out the possibility that the loan player has helped the team in terms of team chemistry, stress management or similar factors but a comparison with other players shows that loan players do not statistically score more goals, have more assists or get more playing time.

H3: Sporting performance is the main driver for the market value development of a loan player.

For the transferring club, it is also interesting to know what the drivers are for the market value development of a loaned player. In addition to the expected negative influence of age on market value, sporting performance in particular can be identified as a driver for the market value development of loan players. A better average mark, goals scored and minutes played have a positive influence on market value development. No differences can be identified here compared to other players who are not on loan. Transferring clubs should therefore pay particular attention to ensuring that loan players go to clubs where they can get match practice. If necessary, this should be verified by means of clauses. Otherwise, they have no direct influence on sporting performance. Other factors, such as position or origin, do not play a role, at least in our model.

H4: Loan players get more playing time than established players.

The minutes played per player contradict the hypothesis put forward here at a significant level, as non-loan players show more minutes played. Although the total number of appearances is not statistically significant, it also contradicts the hypothesis. This is a problem for loan players.

H5: Loan players are younger than established players.

On average, loan players are 1.5 years younger than non-loan players. Furthermore, defensive players are loaned out less often than attacking players compared to the total number of players in Bundesliga seasons. Above all, goalkeepers are loaned out significantly less often and attackers significantly more often.

Our findings complement the research on loan players described in Conceptual Framework. We conclude for the three identified protagonists that no one seems to benefit directly from the loan deal. This counteracts the observed increase in loan transfers, especially internationally, in recent years, which even prompted FIFA to change its rules to reduce them. A possible explanation could be adverse selection. It should also be noted that the loan of a player is generally due to the fact that he is unable to succeed at the loaning club, at least temporarily, and presumably has less game experience. Nevertheless, better teams usually give players to supposedly weaker teams and therefore the players should generally be of a higher standard. Nevertheless, no team is likely to send its key players on loan. Except in the special case of financial bottlenecks, and even then a sale would probably make more sense.

This work is subject to several limiting factors. Firstly, both the scores for player performance and the market values are not objective indicators. Although they are frequently used in research, they are subject to some fluctuations compared to, for example, minutes played, which we have to take into account here. A comparison of market value development was not possible due to the different points in time. We also had to impose restrictions on loans that did not last exactly one season to be able to carry out the analyses. In addition, to be able to compare the loan transfers, we only considered the loans inside the Bundesliga and not the loans out of the Bundesliga. We were unable to analyse the basic strategies of a loan, such as filling squad positions or preparing for player absences, with the available data. All of this must be taken into account when interpreting the results.

We see a need for further research and above all an expansion of the data set to include more European leagues, at least the five largest football leagues to be able to verify the findings obtained here in other leagues. In addition, a study could be carried out in women's football or an extension to other sports could be considered. Furthermore, data on market value developments should be collected daily so that a comparison can be made with the development of other players and age, position and performance can also be checked. Contract modalities with subsequent purchase options could only be reported descriptively and follow-up analyses are also possible here. It could also be possible to analyse the sporting success of recent years and the resulting loan transfers to check whether poorer teams loan players from better teams.

Conclusion

The study aimed to analyse the development of loan players in the German Bundesliga. The main reason for this is the increasing relevance of loan work in professional football and the planned FIFA rule change to reduce player loans. To this end, the literature on the topic was reviewed, 378 loan transfers in the first Bundesliga in the 2010/2011 to 2021/2022 seasons were analysed and a comparison was also made with the 6,162 non-loan players in the Bundesliga. The focus of the study was on the examination of three identified protagonists, the loaned player, the lending club and the loaning club, and what advantages the respective protagonists hope to gain from a loan. About the player, it can be stated that a loaned player does not get more, and in some cases even fewer, minutes than an average Bundesliga player. The loaning club cannot expect a statistically significant increase in the player's market value, which would subsequently result in an improved negotiating position for a player sale. Furthermore, market values also reflect sporting development, which does not appear to have increased. A loaning club hopes that the player will help in sporting terms in the future. This cannot be confirmed, at least when comparing the average grades of the loan players, and those of the clubs, as well as other performance indicators such as goals or assists. These results should be interpreted in the light of the limitations already described. In our analyses, none of the three protagonists appears to benefit directly, which contradicts the increase in loan transfers, particularly internationally, in recent years, which has even prompted FIFA to change its rules to reduce them.

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Heptathlon: The Current Scoring System and its Biases: An Analysis into the Distribution of Scores

By Theresa Vater[*] & Maximilian Vater[±]

Heptathlon is an Olympic combined event including seven track and field events. It is intended to identify the most versatile athlete. Performances from each event are scored using a points system and then summed up to reach a final score. The objective of this study is to examine if the data distribution of the heptathlon scoring system equally represents the seven events and to explore the contribution of each event to the final score. To determine this, a multiple linear regression was conducted on the results of 433 heptathlons from 19 competitions. The results showed that the scores among the disciplines are unequally distributed with throwing events having the smallest proportion (12%) and hurdles having the greatest proportion (17%) on the final score. Track events show, on average, smaller standard deviations (940.06±67.95) in their scores in comparison to field events (836.90±88.62). Long jump seems to be a key predictor for an athlete's final score (B=118.33). Concluding, the current scoring system is not well suited to determine a multitalented athlete. It favors sprinters and jumpers over throwers and should therefore be reconsidered. Further research is necessary to develop a system that treats all events equally.

Keywords: *combined events, scoring system, performance analysis, heptathlon, IAAF*

Introduction

Mathematical Background

Nowadays, combined events are part of the track and field events in the Olympic athletics program. A women's heptathlon consists of 100m hurdles, shot put, high jump, 200m, long jump, javelin throw, and 800m. The current heptathlon world record belongs to Jackie Joyner-Kersee. Who, at the age of 26, achieved 7291 points at the 1988 Olympic Games in Seoul, South Korea (Silva & Caeiro 2021). Because the events have different measurement systems (meters, centimeters, seconds), the performances of each event are transformed into a common points system. This enables the scores to be summed up to a final score which leads to the overall ranking of the athletes. Due to the different measures, the International Association of Athletics Federations (IAAF) established three equations for the different types of events. These equations were derived by Dr. Karl Ulbrich and Jörbeck in 1954. In 1984, the technical committee, under lead of Emmanuel Rose, modified the system which has been used ever since.

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Combined events try to detect a multitalented athlete, someone who can sprint, jump, throw, and has endurance. Therefore, the winner of the decathlon/ heptathlon is crowned as king and queen of athletics (Hartmann 1977). The competition follows the principle of all roundness, which means that every single event should have roughly the same share on the total score (Westera 2007). The IAAF's scoring system should insure that performances in every discipline score approximately the same amount of points (IAAF 2001, Trkal 2006). The current scoring equations consist of three types: a linear, a progressive, and a regressive formula. The progressive curve illustrates an inverse probability of a high score when performances approach record levels. To put it simply, the more outstanding a performance, the less likely it is (IAAF 2001, Trkal 2006).

The constants which are applied in the formulas are shown in table one below. The role of the constants is to weigh the different formulas so the points from each event match the respective performance. The constants have been determined on basis of mean values of the 30 world's best specialists and the 100 worlds' best multiathletes in 1984 (Fröhlich et al. 2017). Since all world records are the limits of human feasibility, the scoring system recognizes them as roughly equivalent (Geese, 2004). Unfortunately, there could be no derivation of the constant's calculation found. There are three constants (A, B, C) for each event which are then inserted into one of the three equations.

Table 1. *Constants of the "IAAF Scoring Tables for Combined Events"*

Event	A	B	C	Unit
200-meter run	4.99087	42.5	1.81	sec
800-meter run	0.11193	254	1.88	sec
100-meter hurdles	9.23076	26.7	1.835	sec
High jump	1.84523	75	1.348	cm
Long jump	0.188807	210	1.41	cm
Shot put	56.0211	1.5	1.05	m
Javelin throw	15.9803	3.8	1.04	m

Source: IAAF 2001, p. 24.

1. Track events include 100m hurdles, 200m, and 800m. They all follow a similar scoring curve to that of hurdles shown in Figure 1. P stands for points scored. A, B, and C represent the constants from Table 1 and T is time in seconds. The regressive curve follows the formula:

$$P = A * (B-T)^C$$

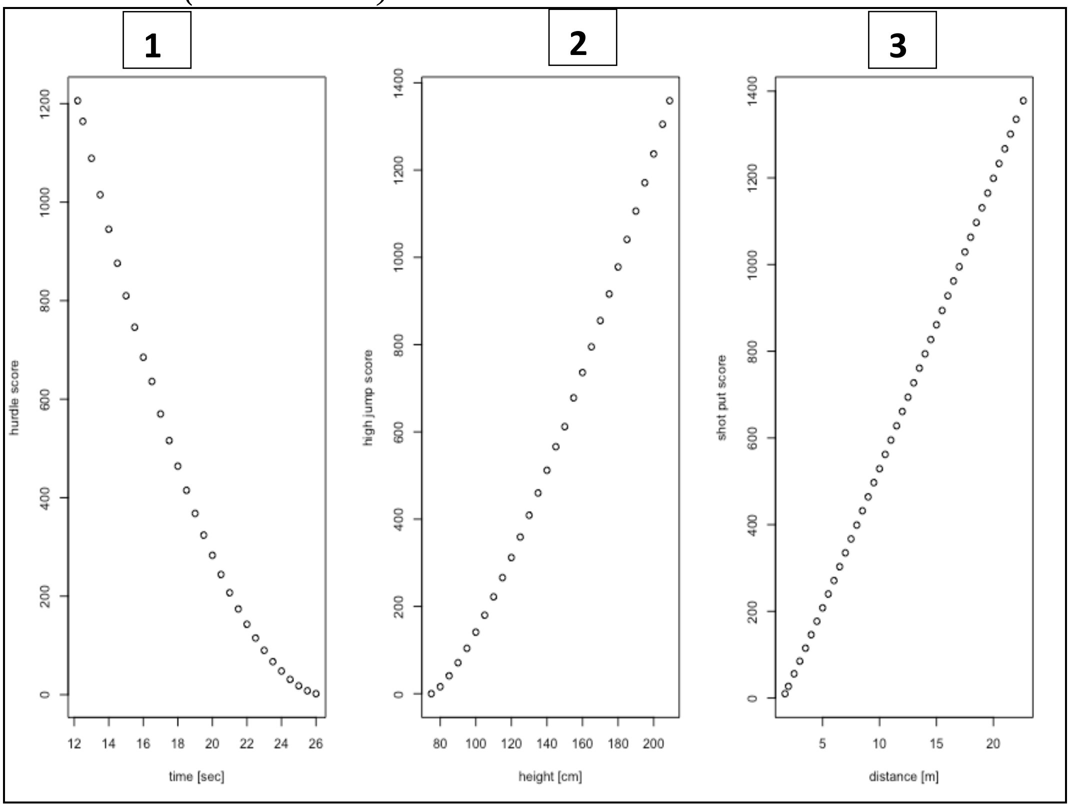
2. Jumping events include high and long jump. In Figure 1, jumping events are represented by the high jump score in column 2. M is the abbreviation for measurement of the jump in centimeters. The progressive curve follows the formula:

$$P = A * (M-B)^C$$

3. Throwing events include shot put and javelin throw. They are illustrated by the shot-put score in the right column with the number 3 in Figure 1. D stands for distance in meters. The linear curve follows the following formula:

$$P = A * (D-B)^{C}$$

Figure 1. *Illustration of the Current Three Heptathlon Equations: Track Events represented by Hurdles, Jumping Events represented by High Jump, and Throw Events represented by Shot Put. Highest score is represented by the Women's World Record (Status 04/2024)*



Source: Plotted with R-Studio by Theresa Vater.

Literature Background

As mentioned above, combined events refer to the principle of all-roundedness and try to detect the most versatile athletes (Barrow 2014, Westera 2007). But is the scoring system even valid for detecting a multitalented athlete?

A pioneer in performance analysis for combined events was Letzelter. In 1985 he already raised concerns about the unequal distribution of points in the scoring system (Letzelter 1985).

The ideal distribution of scores for a multi-athlete who achieves the same number of points from each event, should be approximately 14.3% for each of the seven events (100%:7). But is that the case?

Westera answered that question in his study from 2007, he found that hurdles have the greatest share on the final score with 16%, followed by 15.5% for long jump, 15.4% for high jump, 14.8% for 200m, 14% for 800m, and in the end the two throwing events with 12.3% for shot put, and 11.8% for javelin. Fanshaw found that, on average, hurdles have the greatest proportion on the final score, followed by high jump, 200m, long jump, 800m, shot put, and javelin (Fanshawe 2012).

Besides the studies examining the descriptive statistics of combined events, like Westera and Fanshaw did, researchers tried to outline the uneven distribution of scores among events with a cluster analysis. Schomaker found out that decathletes can be clustered in three types: speed specialists, strength specialists, and endurance specialists (Michael Schomaker 2011). Several authors state that the sprint type is clearly favored over throwers and endurance athletes by the current decathlon scoring system because more points are available from track compared to field events (Barrow 2014, Fröhlich et al. 2017, Geese 2004, Park & Zatsiorsky 2011, Westera 2006).

There seems to be considerably less data for the heptathlon analysis in comparison to the decathlon scoring system. Like Decathlon, heptathlon can be clustered in three groups: 1) Speed type: 100m hurdles, high jump, 200m, long jump; 2) Strength type: shot put, javelin throw; 3) Endurance type: 800m (Fröhlich 2015, Heazlewood 2011). Researchers have found that the speed-based disciplines have a greater impact on the overall outcome compared to the throwing disciplines (Fröhlich 2015, Mekhrikadze et al. 2019, Westera 2007).

Considering, that hurdles seem to make up the greatest share with approximately 16% on the final score and is a speed-based event, the researchers of this paper wondered therefore if hurdles could serve as the greatest predictor for the total score.

In order to predict a heptathlon performance, regression models are used. Brodani discovered that 41% of variance can be explained by long jump. This means, long jump has the greatest influence on the expected value i.e., the athlete's final score (Brodáni et al. 2022). According to Fröhlich long jump has an explanatory power of 48% based on the R^2 value. Whereas in contrast, it is 7-8% for shot put, javelin, and 800m (Fröhlich 2015). According to further literature, the disciplines don't equally affect the final score.

Study Objective

Unfortunately, previous studies showed several limitations in their study samples. For example, small sample sizes and the inclusion of javelin results before 1999. The javelin's centroid was shifted forward in that year due to safety reasons (Backley 2000). That means javelin results before and after 1999 are hardly comparable and could therefore have caused an error in previous studies.

1. Therefore, the objective of this study is to re-examinate the score distribution for a large sample, only including javelin results from 1999 and onwards. The corresponding research question is: Is the data distribution

calculated with the current heptathlon scoring system equally representing the seven single events?
2. Secondly, this paper aims to check which event is the best predictor for the final score. Therefore, the contribution of each event of the final score will be explored. The corresponding research question is: Is the event with the greatest share, also the best predictor for the final score?

Methods

For this study, only heptathlon results achieved in 1999 or later were included. Even though the IAAF calculates with the same tables since 1984, in 1999 the javelin was redesigned to bring the center of mass forward (Backley 2000). This change was made to reduce the distances thrown because the athletes often reached distances close to the end of the field. If no change was made, this could endanger event workers and other athletes outside of the event area and unaware of any potential dangers. Due to this change javelin scores before 1999 are hardly comparable to those achieved in or after 1999. The sample includes heptathlon outcomes of World Championships from 1999 to 2023 and Olympic Games from 2000 to 2021.

Exclusion criteria are the following:

- Abrupted heptathlon
- No marks reached in one or more disciplines
- Athletes caught doping
- Ages outside 18-35

Data was gathered from publicly available sources like https://worldathletics.org/ (*World Athletics*), https://www.sportschau.de (*Sportschau*), and https://www.wikipedia.de (*Wikipedia*). The name, date of birth, nationality, ranking, measurement of each performance, scoring points for each event, and the overall score were entered into Microsoft Excel for processing. 433 heptathlon results from 19 events and 192 athletes were gathered.

To answer the first research question the descriptive statistics includes mean value, median, minimum, maximum, standard deviation, variance, and quartiles. It was conducted with the latest version of JASP 0.17.2.1.

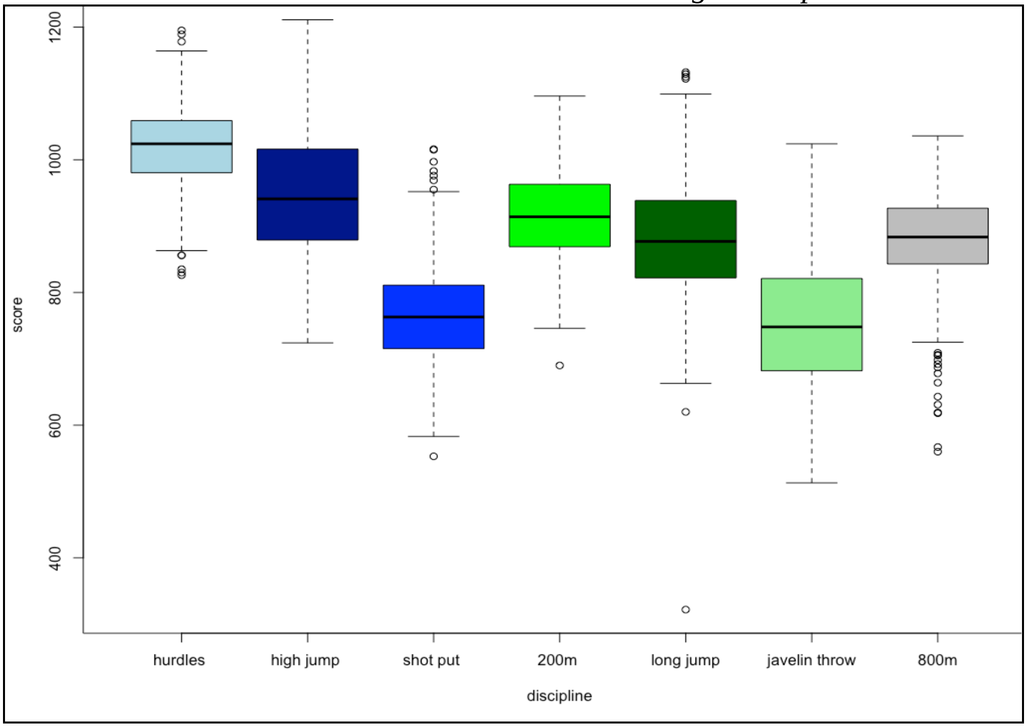
To test how each event, influences the final score, a multiple linear regression was conducted. The dependent variable is the final score, and the independent variables are the performances of seven events. A z-standardization was conducted to make the values of different measurements (m, cm, sec) of the performances comparable. At first, the measured performances had to be transformed into z-values. The z-standardization was calculated by this formula: $z = (\chi - \mu) / \sigma$. The mean ($\mu$) was subtracted from the original value (χ) and then divided by the standard deviation (σ). R-Studio was used for plotting.

Results

First Objective: Distribution of Scores

Figure two illustrates the distribution of the scores for the whole sample (n=433) based on the current IAAF scoring model. The seven disciplines are labeled in order of how they are competed on the x-axis. And on the y-axis are the corresponding scores achieved between 1999 and 2023 for World Championships and Olympic Games for each event. The mean age of the athletes was found at 25±3.5 years.

Figure 2. *Boxplots of Heptathlon Scores from World Championships and Olympic Games between 1999 to 2023 divided into the Seven Single Disciplines*



Source: raw data plotted with R-Studio by Theresa Vater.

The boxplot illustrates that on average the most points (1021±62) were gathered during the 100m hurdle sprint. Meaning on average, it has the greatest proportion of the total score with 16.8%, then high jump with 15.6% (948±88 points). The third greatest proportion is made up by the 200m sprint with 15.1% (916±69 points) followed by 14.5% (881±90) for long jump. The 800m run has on average a proportion of 14.5% corresponding to 880±73 points. The lowest share is accounted for shot put with a score of 761±78 points (12.5%) and javelin throw with 752±101 points (12.4%). The average total score is 6163±318. Most outliers were found for 800m, shot put, and hurdles. Another finding is that the standard deviation is higher for field disciplines (javelin±101, long jump±89, high jump±87, shotput±78) and smaller for track events (800m±73, 200m±69, hurdles±62).

Second Objective: Multiple Linear Regressions

To answer the individual influence of each event on the final score, a multiple linear regression was calculated in JASP. Due to different types of measurements (time or distance) in several disciplines, it is mandatory to transform the measured performance into z-values. The z-values make the various performances comparable.

The overall model predicted approximately 96% of the variance for the total score, R^2=0.957, $F_{(7,408)=}$1295.96, p<0.001. There were only significant associations between disciplines and the total score found (p<0.001).The hurdles (B=-65.06, SE=4.53, p<0.001, 95%CI= -73.96 to -56.14), 200m (B=-70.39, SE=4.67, p=<0.001, 95%CI= -79.57 to -61.21), and 800m (B=-70.81, SE=3.53, p<0.001, 95%CI= -77.76 to -63.87) show negative regression coefficients. Indicating the fewer the seconds, the greater the final score.

Vice versa, high jump, shot put, long jump, and javelin throw all show positive coefficients. Indicating the further or higher the jump/ throw, the greater the score. Long jump (B=118.33, SE=4.09, p<0.001, 95%CI= 110.28 to 126.37) has the greatest influence on the predicted score. It is followed by javelin (B=102.47, SE=3.60, p<0.001, 95%CI= 95.38 to 109.55) and shot put (B=85.85, SE=3.53, p<0.001, 95%CI= 78.92 to 92.78). For high jump it is B=49.37, SE=3.41, p<0.001, 95%CI= 42.67 to 56.01. Meaning a one-unit shift of the z-standardization for high jump indicates a mean change in the final score from 6162.5 + 49.37 to 6211.8.

Table 2. *Multiple Linear Regression*

Multiple linear regression						
Event	**Regression Coefficient B**	**SD**	**Standardizied regression coefficient ß**	**p-value**	**lower limit**	**upper limit**
Hurdles	-65.06	4.53	-0.204	<0.001	-73.96	-56.14
High jump	49.37	3.41	0.155	<0.001	42.67	56.01
Shot put	85.85	3.53	0.270	<0.001	78.92	92.78
200m	-70.39	4.67	-0.221	<0.001	-79.57	-61.21
Long jump	118.33	4.09	0.372	<0.001	110.28	126.37
Javelin throw	102.47	3.60	0.322	<0.001	95.38	109.55
800m	-70.81	3.53	-0.223	<0.001	-77.76	-63.87

Discussion

First Research Question: Is the Data Distribution Calculated with the Current Heptathlon Scoring System Equally Representing the Seven Single Events?

According to the descriptive statistics, this study proved for a great sample (n=433) that the scores are unequally distributed. Shot put and javelin are particularly neglected in the athlete's final score. Descriptive statistics showed different proportions of the seven disciplines. The hierarchy found in this study is: hurdles (16.8%), high jump (15.6%), 200m (15.1%), long jump (14.5%), 800m (14.5%), shot put (12.5%), and javelin (12.4%).

The same share order is shown by Fanshawe (2012). Westera found a slightly different hierarchy for his sample of the all-time top 99 women's heptathlon which is: hurdles (16%), long jump (15.5%), high jump (15.4%), 200m (14.8%), 800m (14%), shot put (12.3%), and javelin (11.8%) (Westera 2007). Westera's Top 99 sample scores higher in long jump than this study's sample, leading to a different order where long jump has the second greatest proportion behind hurdles. So, it seems that the all-time top list is dominated by extraordinary long jumpers. Summing up, different samples lead to a different order of events in terms of shares on the final score.

Looking at the spread of the performances among all athletes, it is noticeable that the standard deviation is higher for field disciplines (javelin±101, long jump±90, high jump±88, shot put±78) and smaller for track events (800m±73, 200m±69, hurdles±62).

These findings go hand in hand with the one from Cox who examined decathlon samples. He concludes that decathletes who perform well in field events are favored in the final ranking (Cox & Dunn 2002). On the first look, this conclusion sounds contrary to the statement that sprinters (=track discipline) are favored over throwers (=field discipline). But is means that sprint disciplines share the greatest proportion of the final score and have a small standard deviation. This indicates that all athletes perform very well there. A strong foundation of sprint abilities is a prerequisite for multi-athletes.

Whereas with field disciplines, there is a smaller proportion of the final score, but wider standard deviations. Indicating that not everyone is performing very well there. These disciplines therefore serve to stand out from the crowd and achieve a better placement.

Perhaps one reason for a greater standard deviation in the field disciplines, especially javelin (±101) is because athletes are aware of the fact that there are not so many points to be scored here due to the scoring system. Smajlović states that improvement of 1cm in high jump equates to 0.111s in hurdles, 0.162s in 200m, 1.09s in 800m, 4.06cm in long jump, 15.74cm in shot put, or 54.19cm in javelin (Smajlović 2008). In competitions the high jump steps are increased by 3cm. If an athlete now fails only 1 further height, she needs to throw the javelin more than 1.5m further to compensate that! These small improvements in running and jumping events leading to large amounts of points, making it easier for athletes to get points from these disciplines as opposed to throwing disciplines. In order to still create an incentive to train the throwing disciplines, the scoring system should be changed.

As a sidenote, it should be mentioned that the most outliers are found for the 800m run. According to literature, the accumulation of outliers here could be described as a “last-event factor” (Schomaker & Heumann 2011, p. 11). This discipline may not reflect endurance performance itself. It is distorted by the already existing score of the previous performances. For example, Bryan Clay (USA) led the first nine events in the Olympic Decathlon 2008, becoming last place in the 1500m run, being sure to win anyways (Schomaker & Heumann 2011).

Summarizing, the first section of the study proved that the data distribution calculated with the current heptathlon scoring system does not equally represent the seven single events.

Second Research Question: Is the Event with the Greatest Share, also the Best Predictor for the Final Score?

The multiple linear regression revealed long jump as the greatest predictor (B=118.33) for the final score. The remaining field disciplines have the following coefficients: javelin=102.47, shot put=85.85, high jump=49.37. The track disciplines show negative regression coefficients (hurdles=-65.06, 200m=-70.39, 800m=-70,81). Indicating the less time, it takes an athlete to reach an aim, the more points are scored.

Literature research showed different statistical procedures among studies. Fröhlich performed seven ordinary linear regressions and calculated that 48% of the variance of the total score can be explained by long jump. It is followed by a R^2 of 38% for 200m, 33% for hurdles, and 21% for high jump. Javelin, shot put, and 800m predict only 7-8% of the variance of the final score (Fröhlich 2015). If one runs several ordinary linear regressions, significant influences can be present in all coefficients. They might lose these as soon as you control for the influence of other variables, meaning, the more variables are controlled, the more realistic the model is. For this reason, a multiple linear regression is preferred over multiple single linear regressions. Brodani, who performed a step regression, points out the long jump (41.59%) as a key predictor for the overall score. But in contrast, he states that shot put (14.54%), javelin (11.29%), and 800m (13.11%) are most valid to predict the final score (Brodáni et al., 2022). There are many statistical ways to analyze performances which lead to different findings. However, researchers with different methods come to the same conclusion, that long jump is a key factor for the prediction of the final score in heptathlon.

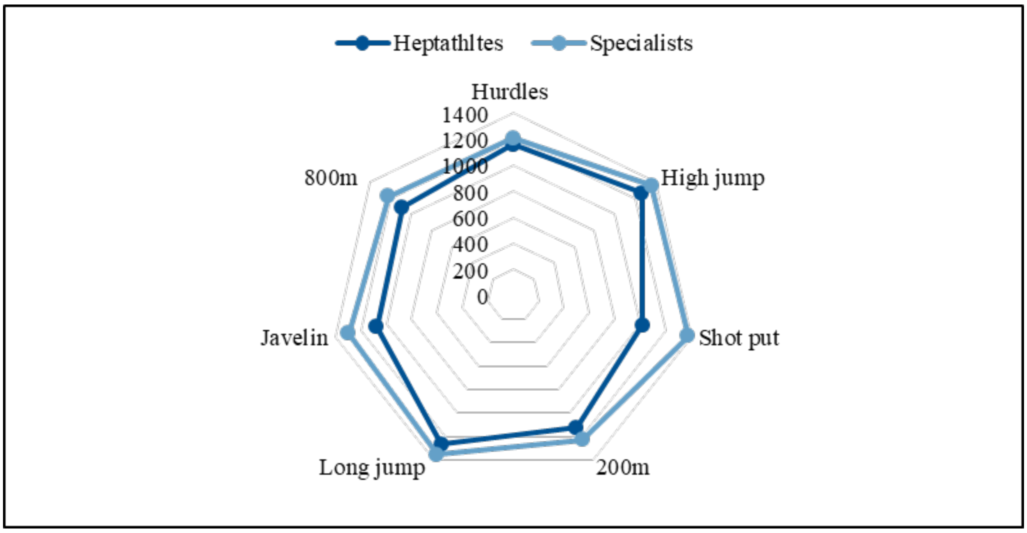
Summarizing, the second part of this paper, which was the exploration of the contribution of each event of the final score, revealed long jump as the greatest predictor. It is not the hurdle sprint, which is the event with the greatest share, that predicts the final score at best.

These findings can be outlined when looking at world-lead heptathlon performance of Jacky Joyner Kersee from 1988. Jacky stands out because she is additionally holding the heptathlon single event record of long jump with 7.27m

(IAAF 2024). This example once again underlines the importance of this discipline, but it still doesn't answer the question why the heptathletes score so few points in the throwing disciplines. Is it solely due to the scoring system?

Perhaps the reason why the throwing performance remains below average could be attributed to the limitation in heptathletes' ability to achieve greater distances due to their phenotype. Multi-athletes are far from looking like throwers (Broekhoff et al. 2003, Houtkooper 2001, Thorland et al. 1981). Clustering somatotypes of various track and field events showed that heptathletes and sprinters belong to the mesomorph type whereas throwers seem to be more endomorphic (Broekhoff et al. 2003). The different anthropometric properties seem to be reflected in the events. To emphasize this statement, Figure 3 illustrates heptathlon records in dark blue and world records of specialist shown in light blue. As you can see, the widest range is found for throwing disciplines. The disciplines where heptathletes differ anthropometrically the most from specialists. In addition to the large discrepancy in the shot put, it must be mentioned that the world record (22.63m) dates back to 1987. The recent title holders of the Olympic Games 2021 (20.58m) and world championships 2023 (20.43m) throw about 2m less. Reconsidering that the current scoring system uses the constants which were calculated on performances from the eighties makes the scoring system look obsolete. Which is another reason to update it.

Figure 3. *Radar Chart of the Women's World Records versus Heptathlon Records; Status 04/2024*



Source: Created by Theresa Vater.

There are several authors stating different approaches for the reevaluation of the system (Grammaticos 2007, Jiyingo & Xinmin 1995, Russomanno & Anselmo 2008, Westera 2006). Russomanno, introduces in his conference paper from 2008 a system which only considers two equations, instead of the current three formulas, for time-based and measurement-based events. Also he uses for the reference value a heptathlon record only and is not comparing heptathletes to specialist (Russomanno & Anselmo 2008). A systematic review should be written comparing all the available models with each other.

Summing up, the descriptive statistics showed a highly uneven distribution of points. The greatest percentage of the final score is accounted to hurdles (16.79%), the lowest to javelin (12.4%). Indicating, that the scoring system itself is biased and less points are scored in throwing events compared to jump or sprint events. Looking at the rankings and Westera's study of the top 99 sample, it seems that the winners are overrepresented by athletes who perform well in jumping disciplines (Westera, 2007). Therefore, the current scoring system goes against the fundamental concept of organizing a competition for multi-talented athletes.

Looking solely at the performances, disregarding the scores of the single events, to check which event influences the final score most, long jump (B= 118.33) was detected as a key predictor, directly followed by javelin and shot put. It seems that the winners stand out especially in these events in order to score particularly high. But even tough an athlete performs over average in these events, the share on the final score is still smaller compared to an average hurdle score. For example, Anouk Vetter threw the javelin at the World championships 2023 in Budapest 59.57m which is close to the heptathlon record of 60.90m corresponding to 1046 points. Form descriptive statistics we know that score equals a median hurdle performance of 1026 points. That extraordinary example displays how hard it is to gather "good" points from throwing events and why most heptathletes don't want to put "too much effort" in throwing events even though they could play the decisive role on the podium. This example once more outlines the importance of updating the current system, so record-like performances get the points they deserve. A possible solution could be the elimintaion of the linear equation and including the throwing events into the progressive function (see Figure 1).

Limitations and Strength of the Study

This study is characterized by a particularly large (n=433) and broad (EC, WC, Olympic Games) sample size to describe the underlying problem. On one hand a large sample size is representative on the other hand it is easier to find significant effects. For the multiple linear regression, it would be interesting to see which values in cm, m, and sec correspond to an improvement of a z-unit. This would make to results easier to understand and should be implemented by further studies.

Due to the changed center of gravity of the javelin in 1999, it could have been that previous studies are biased in their results examining throwing events. The re-evaluation of the point distribution was therefore carried out in this study, in particular to eliminate this bias.

Conclusion

This study proved that the current heptathlon scoring system shows an unequal distribution of scores among the seven disciplines. It especially neglects throwing events (shot put and javelin) which on average make up 12% of the final score and favors sprinting disciplines (hurdles and 200m) with an average proportion of 16%. Even extraordinary performances in throwing events don't seem to gather noticeable more points than an average hurdle performance. The multiple linear regression revealed that long jump is the greatest predictor for the final score, followed by javelin.

The IAAF should reconsider their current scoring system. There are already several approaches by different researchers available. These authors recommend calculating the constants based on previous records of heptathletes/decathletes solely. Hopefully this could lead the seven disciplines into balance with one another. But because there are so many different mathematical approaches for the scoring systems of combined events, a systematic review is required to evaluate which model is most appropriate, so all disciplines of heptathlon carry the same weight.

Another approach to lead combined events to a balanced distribution of endurance, throwing, jumping, and sprinting events could be the rearrangement of the disciplines. For example, additional disciplines like discus and 1500m could enhance the weighting of endurance and throwing events. Of course, it would have to be checked whether this proposal would receive support from the athletes. But if the system does not change, athletes should consider which discipline is worth investing the most training time into.

This paper identifies the underlying issues with the current heptathlon scoring system, raising further questions that could guide the development of an alternative system. Therefore, this study serves as a catalyst for additional research in the field of heptathlon.

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Athens Journal of Sports - Volume 11, Issue 3, September 2024 – Pages 165-178

Effectiveness of Stretching Routines in Enhancing Kicking Performance

By Jessica H. Esparrago[*] & Adeva Jane Esparrago - Kalidas[±]

This study was undertaken primarily to determine the effectiveness of stretching routines in enhancing kicking performance in Karate. Quasi-experimental design was used, involving two (2) karate classes, involving a total of 62 participants. The combined stretching routine of Hamstring Stretch and Seat Straddle Lotus were used for Stretching Routine 1 and Side Split and Seat Side. Straddle Lotus were employed for Stretching Routine 2. Matching was observed, and Wilcoxon signed rank test was used to determine the difference between the pretest and post test scores of the students; and the Mann-Whitney U Test was used to determine the difference between the performance of the two groups. The study revealed that the majority of the participants' kicking performance showed the need for improvement during the pretest. After administering the stretching routines, with one group using the Hamstring Stretch and Seat Straddle Lotus, and another Side Split and Seated-Side Straddle, it was found that the two (2) groups' kicking performance improved to a 'good' level. A significant difference was found between the pretest and posttest, implying an improvement in their kicking performance and level of flexibility. The increment of the two groups' performance did not significantly differ; hence, both the stretching routines are equally effective in enhancing the kicking performance of the students.

Keywords: *flexibility, hamstring stretch, seat straddle lotus, side split, seat side straddle*

Introduction and Literature Review

Karate, as martial arts and system of self-defense, originated hundreds of years ago in Okinawa but was greatly influenced by an even older tradition from the state of China (Cowie & Dyson 2016). Karate-do is one of the most popular martial arts in the world which involves using the body as an ultimate weapon against various forms of attacks (Cynarski 2017). It consists of different techniques of blocking, punches, and kicks to deliver an effective means of defense and offense. Although arms are commonly used in Karate, since the legs are normally used to support the body, they are utilized more (Oyama 1998). The legs are also much stronger than the arm, and because of its superior length the legs are used to attacking from a greater distance, thus, to develop sufficient strength and flexibility of legs is to therefore acquire the strongest weapon in an unarmed man's arsenal (Gavagan & Sayers 2017). This is apparent in Karate competitions wherein most of the winning blows are delivered by the leg,

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particularly through the roundhouse kick *(mawashi-geri)* (Sterkowicz & Franchini 2009).

However, effective technique performance is not done overnight. Before progressing to formula of techniques, every Karate student must be prepared and conditioned physically to prevent injuries and strains in the execution of techniques; hence, as a Karate student, it is imperative to be physically fit and to be flexible with the aid of different routines (do Nascimento et al. 2023).

Among the many problems encountered by Karate Instructors is the flexibility of the kicking legs (do Nascimento et al. 2023). But flexibility is not limited to athletes alone- an awareness of proper stretching techniques may also benefit non-athletes or non-Karate practitioners (Law et al. 2009). As observed, only a few who exercise take the time to stretch, and only a few of those who stretch do it properly (Ayala et al. 2013). When joints are not regularly moved through their entire range of motion, muscles and ligaments shorten in time and flexibility decreases- without proper stretching, even if one does regular exercise such as running, cycling, or aerobics, there is a tendency that muscles and ligaments to tighten (Walker 2013). Most fitness participants underestimate and overlook the contribution of good muscular flexibility to overall fitness leading to muscular and skeletal problems and injuries (Slobounov 2008). In daily life, one often must make rapid or strenuous movements and abruptly forcing a tight muscle beyond its achievable range of motion may lead to injury (Hoeger & Hoeger 2014).

In developing flexibility, it is apt to remember that it is a complex skill which requires several skills subsets and is affected by several factors (Batista et al. 2019). Hoeger & Hoeger (2014) cite the benefits of good flexibility which include promoting healthy muscles and joints, improving elasticity of muscles and connective tissue around joints and enabling greater freedom of movements and the individual’s ability to participate in many types of sports and recreational activities. Adequate flexibility also makes activities of daily living much easier to perform (Tidman & Skotzke 2020). Taking part in a regular stretching program increases circulation to the muscles being stretched, prevents low back and other spinal column problems, improves and maintains good postural alignments, promotes proper and graceful body movement, improves personal appearance and self-image, and helps in the development and maintenance of motor skills throughout life (Behm et al. 2016).

Regular stretching helps decrease the aches and pains caused by psychological stress and contributes to a decrease in anxiety, blood pressure and breathing rate (Kwok et al. 2019). Stretching also helps relieve muscle cramps encountered at rest or during participation in exercise (Maughan & Shirreffs 2019). Mild stretching exercises in conjunction with calisthenics are helpful in warm-up routines to prepare for more vigorous aerobics or strength-training exercises and in cool down routines following exercise to facilitate the return to a normal resting state (Draper 2016). Fatigued muscles tend to contract to a shorter than average resting length and stretching exercises help fatigued muscle re-establish their normal resting length (Colby et al. 2017).

Considering that flexibility is a component of health–related physical fitness, it is imperative for one to learn stretching as a primary technique. Regular stretching exercises promote flexibility that permits freedom of movement, contributes to ease and economy of muscular effort, allows for successful performance in certain activities and provides less susceptibility to some types of injuries or musculoskeletal problems (Corbin et al. 2006). The critical role of stretching routine to man's physical fitness impels the researcher to conduct this study.

This study assumes that the stretching routines, specifically side-straddle lotus, hamstring stretch, side-split and seat-side straddle, are effective in developing flexibility as demonstrated by students' kicking performance. It also assumes that better flexibility is achieved through stretching routines as manifested through the performance of the roundhouse kick (*mawashi-geri*). Flexibility is very much needed when engaging in all types of activities, whether in sports or exercises (Law et al. 2009). However, many jobs that require sitting for long periods of time may result in muscles losing its elasticity, which diminishes joint flexibility resulting to shortened muscles and lack of mobility of the body (Nelson & Kokkonen, 2020). Good flexibility, which requires strong muscles, is an important means of injury prevention especially when engaging in activities such as Karate-do, swimming, track and field events, gymnastics and other martial arts, and even in everyday activities (Franchini & Herrera-Valenzuela 2021).

Most importantly, people with greater flexibility have greater reach (Knudson 2018). They can push off the rear leg and send their hips far forward without raising them. They can lift their knees and unload a kick as much as two feet greater stable range while stepping in. If caught, they are far less likely to lose their balance or be injured. If they overstep or slip and fall, they are more likely to recover without harm (Redmond 2008).

There are two types of flexibility. The first type is static flexibility which refers to the range of motions that can be achieved through a slow and controlled stretch. The second type is dynamic flexibility which refers to the range of motion achieved by quickly moving a limb to its limits (Burgess et al. 2009). The importance of flexibility can be best associated with almost all sporting events. Primarily, this is one of the many pre-requisites to become a good athlete in Karate-do as show through performance of the roundhouse kick (*mawashi-geri*).

Considering that basic kicking is emphasized for beginners, exercises like Front Kick (*Mae-geri*), Side Kick (*Yoko-geri*) and Roundhouse Kick (*Mawashi-geri*) are oftentimes repeatedly practiced. In particular, the study focuses on the Roundhouse Kick (*Mawashe-geri*) as this is the most difficult kick that most students find hard to execute (Abdel Fattah Alserssi 2014). Oyama (1998) mentions that the Roundhouse Kick (*Mawashi-geri*) starts by bending the knee and bringing it to the side position and the body is bent away from that side. Then, using a large circular motion, one extends the foot forward and strikes the jaw, face or side of the body of the opponent. If the timing is correct, this kick can express a tremendous amount of power. Roundhouse kicks are commonly used in sparring (*Kumite*) competitions because proper execution of the techniques earns a greater deal of points as compared to other attacks since the technique provides the participant a longer reach since the leg has obviously greater reach than the arms (Gavagan & Sayers 2017).

The succeeding paragraphs describe the stretching routines for implementation to help the body either warm up or cool-down for specific activities (Powers et al. 2009).

First is Hamstring stretches, specifically the Sitting Single Leg Hamstring Stretch. This stretch is done through sitting with one leg straight out in front and toes pointing upwards. The other foot is then moved towards the knee. The students will then let their head fall forward and reach towards their toes with both hands (Walker 2007). This stretch affects the semimembranosus, semitendinosus, and bicep femoris muscles. The first stretching exercise is the Hamstring stretches which one can do to prevent injuries. Hamstrings are often overlooked during strengthening because they are on the back of the body. Muscle imbalances often predispose people to injuries. Stretching hamstrings is also important to prevent back injuries. Tight hamstrings prevent the forward tilt of the pelvis causing more pain of the lower back. The lower back is not designed to withstand the forces exerted on it in a forward bending position when lifting. All three muscles act to flex the knee. This exercise is helpful for the roundhouse kick (*mawashi-geri*) as the semimembranosus and semitendinosus muscles are the ones which act to extend the hip (Eveleigh 2013).

Another exercise is the Seat-Side Straddle, also known as Reverse Side Hurdle Sitting or Siting Reach Forward Hamstring Stretch, which is a stretch executed by sitting on the floor and the legs are spread out in a half-split position, just like jumping over a hurdle, but seated (Walker 2007). The forearms (or elbows) are placed on the gap in the middle of the legs and the body is pushed downward, holding the final stretch for several seconds (Werner & Hoeger 2012). Seat-Side straddle targets the hamstrings, semimembranosus, semitendinosus, biceps femoris, extensor muscles and erector spinae (Walker 2007, Alaia 2010). This stretch is helpful for the roundhouse kick (*mawashi-geri*) as it is the initial position before kicking (Oyama 1998).

The first two stretches are done in combination as they both target the hamstring muscles, semimembranosus, semitendinosus, biceps femoris, extensor muscles and erector spinae. Stretching exercises which target the hamstrings are important in developing kicking as these muscles facilitate a better range of motion for hip flexors (Haddad 2014), for medial and lateral rotation of the hip (Park & Lim 2023), and for leg rotation during knee extension (Kimura 2023). Stretches targeted toward the hamstrings often indicate the viscoelastic and lengthening changes of the hamstrings, which means less tension and stress when the muscles are used (Meroni et al. 2010).

Next is the Seat Straddle Lotus, also called Groin Butterfly Stretch or Sitting Adductor Stretch, which refers to the stretch executed by sitting on the floor and the feet are brought close to the soles of the feet allowing them to touch each other. The forearms (or elbows) are placed on the inner part of the thigh and the legs are pushed downward, holding the final stretch for several seconds (Werner and Hoeger 2012). This stretch works on the inner thigh muscles in its basic version, specifically, the adductor muscles - adductor longus, brevis and magnus, and some muscles on the back of the thighs as well. The Seat Straddle Lotus is great because most people forget that they should think of their torso occasionally, but it can be injured like any other body part (Knox, 2015). This stretch is important in the execution of the roundhouse kick (*mawashi-geri*) as adduction strength is important for kicking and acceleration (Jensen et al. 2014).

Lastly, there's the Side Split which refers to the stretch executed by sitting with the legs spread apart as far as possible to either side. This is a variation of the Sitting Wide Leg Adductor Stretch in which the hand touches both toes and leans forward until the chest almost touches the floor, with the leg kept flat on the floor (Walker 2007). This stretch targets transversus abdominis to compress abdomen and stabilize lumbo-pelvic region, it also targets the adductor longus, brevis and magnus (Walker 2007). It also employs deep pelvic floor to aid in firing transversus and obliques and erector spinae to stabilize torso. Target areas also include abdominals and hip extensors to stabilize pelvis and hip abductors concentrically to press carriage out, eccentrically on return (Merrithew 2009). The Side Split stretch develops the flexibility of the lower limbs, which is useful in a difficult kick like the roundhouse kick (*mawashi-geri*) (Penov & Chalukov 2019).

The second stretching combination both target adductor muscles- adductor longus, brevis and magnus, which provide a useful source of flexor and extensor torque at the hip (Sheng et al. 2016) and provide high levels of stability protection for the hip and knee of the pivot leg during a kicking motion (Chang et al. 2021). Each individual adductor muscle aids in femoral flexion and rotation (Nicholas & Tyler 2002). It is therefore important to properly stretch them as decrease in the strength of the adductor musculature can be the cause of an increased risk of injury in many sports and activities wherein changes of direction or accelerations are characteristic (Whittaker et al. 2015).

A decline in flexibility can cause poor posture and subsequent aches and pains that lead to limited and painful joint movement. Inordinate tightness is uncomfortable and debilitating (Hoeger & Hoeger 2014). This is supported by Corbin et al. (2006) who claimed that maintenance of flexibility is a life-long process. The reduced activity fosters loss of flexibility and the cycle continues. Thus, to give further emphasis to the importance of flexibility not just among athletes, but especially among non-athletes, this study attempted to determine the levels of flexibility of the Physical Education male Karate students using the stretching routines Hamstring Stretch and Seat-Side Straddle, as well as the Seat-Straddle Lotus and Side-Split to Roundhouse Kick (*Mawashi-geri*) performance and comparing the effectiveness of the stretching routine combinations between each routine and between groups.

Materials and Methods

The study utilized the quasi-experimental design as defined by Campbell (2002) as the process of conducting an initial observation (pre-test) to the group of participants, and then to administer a treatment and finally, to conduct the second observation (post-test). In this study, two different stretching routines were introduced to two different groups.

The population was made up of two separate Karate classes in a physical education setting. The respondents were all males in second year college, aged around 17-19 years old. Each class consisted of 31 male students in each group. The Karate class took place three times a week for 2 hours per class for six months, or one semester. The participants undertook both pre-test and post-test to determine the kicking performance increment after exposure to the two different interventions. The participants of this study were taken from six sections enrolled in Physical Education. The participants were divided into two groups- where one group performed the Hamstring Stretch and Seat Straddle Lotus, while the other group used the Side Split and Seat Side Straddle as the stretching routines program. The groups' stretching techniques were limited to the ones assigned to them. Both classes were Karate classes which included a lecture-demonstration of different Karate techniques. For this class, the focus was on kicking, particularly on the roundhouse kick (*mawashi-geri*).

The intervention was the Stretching Routines- which included the Hamstring stretch and Seat-Straddle Lotus, and the Side Split and Seat Side Straddle combination stretching routines. The dependent variable was the students' kicking performance. Rubrics were then used to determine the participants' performance levels for the roundhouse kick. Criteria included patterns in movement, and proper delivery of the kick to its target. This rubric was validated by an expert on Karate - Shihan Masayuki Iwabuchi and an expert on physical education – Dr. Edna delos Santos. The rubric is as follows:

	Needs Improvement 1	**Acceptable 2**	**Good 3**	**Outstanding 4**
Skill on kicking focus Round house kick (Mawashi-geri)	Round house kick hitting below hip level is weak and needs improvement; unsure of proper techniques but sometimes successful in executing them; knows and tries to follow movement patterns required in executing corrected performance in round house kick	Round house kick hitting hip level is adequate; tries to use proper techniques and is often successful in executing them; knows and tries to follow most movement patterns required in executing corrected performance in round house kick	Round house kick hitting the body or rib level is generally good. Mostly, uses proper techniques and are successful in executing them. Attempt to apply the necessary skill in round house kick movement pattern in karate tournament and self-defense technique	Round house kick hitting face level is superior; uses proper techniques and is successful in executing them; knows and always follows movement pattern; helps others to develop their own skill in round house kicking learned to karate tournament and self-defense techniques

A letter requesting for students' data on participant's height, weight and blood pressure information via health records was also done. Instructions were disseminated to all participants to avoid additional strenuous physical activity over the duration of the study. Such measures were taken to ensure that no other factor may influence their performance. The participants were required to wear proper PE uniform during the conduct of the study.

Each testing session started with the standard 15-minute warm-up and stretching procedure, followed by the two different stretching routines. The two stretching routines were administered on the same schedule or time of the day in the afternoon. Using Kicking Pad as an instrument to determine target and the kicking performance, the participants were asked to use the dominant leg to perform the Round House. The two experimental groups of Physical Education male Karate students were assigned to the two different combined stretching routines which are the Hamstring Stretch with Seat Straddle Lotus (groin butterfly stretch) and the Side Split with Seat Side Straddle (reverse side hurdle sitting).

Descriptive statistics such as the frequency, percentage, mean and standard deviation were used to organize the data in Problem 1. Considering that the data were not normally distributed as shown by the Kolmogorov- Smirnov (.367, p=. 00) and Shapiro-Wilks (.693, p=.000) test, nonparametric statistics were used. To determine the difference between the pre-test and post test scores of the participants' kicking performance, Wilcoxon signed rank test (the non-parametric equivalent of t test for paired samples) was used; and to determine the difference in the students' performance between groups, Mann-Whitney was used (the non-parametric equivalent of the t test for independent samples). Descriptive statistics such as frequency, percentages and mean were used to describe the variables of the study.

Results

This section features the findings, analysis and interpretation of the data. The gathered data are presented and sequenced according to outlined objectives.

Problem 1. What are the participants' kicking performance before and after the stretching routines?

Table 1 shows the frequency, percentage and mean distribution of participants' kicking performance before and after exposure to the two sets of Stretching Routines namely Hamstring Stretch and Seat Straddle Lotus and Side- Split and Seat Side Straddle.

Table 1. *Frequency, Percentage and Mean Distribution of Students' Kicking Performance*

Scale	Range	Decription	Stretching Routine 1 Hamstring and Seat Straddle Lotus				Stretching Routine 2 Side-Split and Seat Side Straddle			
			Pretest		Post Test		Pretest		Post test	
			f	%	*f*	%	*f*	%	*f*	%
4	3.51-5.0	Outstanding	0	0	1	3.23	0	0	0	0
3	2.51-3.50	Good	1	3.2	15	48.4	1	3.2	5	16.13
2	1.51-2.50	Acceptable	12	38.7	13	41.9	12	38.7	17	54.84
1	1.0-1.50	Needs Improvement	18	58.1	2	6.45	18	58.1	9	29.03
		Total	31	100.0	31	100.0	31	100.0	31	100.0
		Mean	1.45							
		SD	.568		.716		.568		.626	
		Description	Needs Improvement		Good		Needs Improvement		Good	

It can be gleaned from the table that both groups improved in their kicking performance from "needs improvement" classification to "good" category. Generally, a higher mean was detected among Stretching Routine one (2.79) often the intervention as compared with the Stretching Routine two with the over-all mean of 2.68 in the post test.

Furthermore, it is interesting to note the significant decrease of the number of participants who are assessed as "needs improvement" in their kicking performance. After experiencing the Hamstring and Seat Saddle Lotus, from 18 the number was reduced to only two participants needing improvement. This phenomenon was not seen with the Stretching Routine two. Out of the 18 participants assessed as needing improvement, there were still nine among them who remained in the "needs improvement" classification.

The figures also reveal that most of the participants in the Stretching Routine one was in the "good" category (48.4) after the intervention. This was followed by 41.9 percent of them with acceptable assessment in their kicking performance.

Meanwhile, the majority (54.84%) of students who performed the Stretching Routine two were on the "acceptable" level after the stretching intervention. This was followed by 29.03 percent who were still in the "needs improvement" classification even after the intervention.

Worthwhile mentioning is the lone participant who got "outstanding" assessment in his kicking performance having been exposed to Hamstring and Seat Saddle Lotus. However, none among the participants of Stretching Routine two got an outstanding assessment.

Nevertheless, both stretching routine groups showed increases in their kicking performance after their stretching routines exposures. The data shows that both stretching routines do improve kicking performance after exposure.

Problem 2. How do the participants' kicking performance compare before and after the stretching routines?

Ho1: The participants of each group do not significantly differ in their kicking performance before and after the stretching routines.

Considering that the data do not meet the requirements for a t test, the non-parametric equivalent Wilcoxon Signed Rank test was used. Table 2 presents the differences in the students' kicking performance before and after the stretching routines. Data show that in both groups, none of the participants got scores that are lesser than the pretest (negative scores); 31 participants had higher post test scores than their pretest (positive scores) and one participant got the same pretest and posttest results.

Table 2. *Wilcoxon Signed Ranks and Z Values Showing Differences in the Students' Kicking Performance Before and After the Stretching Routines*

Signed Ranks	Stretching Routine 1 Hamstring and Seat Straddle Lotus				Stretching Routine 2 Side-Split and Seat Straddle				
	N	Mean Rank	Z	P	Signed Ranks	N	Mean Rank	Z	p
Negative Ranks	0	.00	4.82**	.000	Negative Ranks	0	.00	4.85**	.000
Positive Ranks	30	15.50			Positive Ranks	30	15.50		
Ties	1				Ties	1			
Total	31				Total	31			

Legend:
Negative Ranks: Post test < Pretest
Positive Ranks: Post test > Pretest
Ties: Post test = Pretest
** significant at 0.01 level

The result shows an increase in the mean rank (.00 versus 15.50) among all the participants. In this test, it is assumed that data are paired and come from the same population; each pair was chosen randomly and independently, and the data were measured at least on an ordinal (and not nominal) scale. The Wilcoxon Signed Rank test shows that the observed difference between both tests is significant in group one (Z=4.82, p= .000) and group two (Z=4.85, p=.000). Thus, the null hypothesis which states that participants' kicking performance do not significantly differ is rejected.

Sufficient data show that the students had marked improvement in their kicking performance. Significant differences were detected in their performance after they were exposed to both stretching routines. This shows that both routines prove to be effective in improving the students' kicking performance.

Problem 3. Which of the two stretching routines significantly improved the participants' kicking performance?

Ho2: None of the stretching routines work more effectively in enhancing the participant's kicking performance.

The non-parametric equivalent of the T test for independent samples, namely the Mann- Whitney test was performed, and the data are presented in Table 3 below.

Table 3. *Mann-Whitney (Z) Values Showing Significant Differences of the Two Groups of Students' Kicking Performance*

Kicking Performance	Stretching Routine 1 Hamstrung and Seat Straddle Lotus Mean Rank	Stretching Routine 2 Side-Split and Seat Side Straddle Mean Rank	*Z*	*P*
Pretest	31.50	31.50	.000	1.00
Post Test	33.18	29.82	.750	.453
Increment	32.73	30.27	.556	.578

The results of the Mann-Whitney (Z) values show an increment of 32.73 for stretching routine group one. Meanwhile, an increment of 30.27 was detected among the stretching routine group two.

Findings show that there is no significant difference between the participants' kicking performance considering the two stretching routines as shown in the participants' post-test (Z=.750, p=.453) and in the increment (Z=.556, p=.578). The two stretching routines, Hamstring Stretch and Seat Straddle Lotus and Side-Split and Seat Side Straddle do not show any significant differences. This can be because both stretching routines target similar muscles which are the lower extremities, and both stretching routines have the same number of repetitions of sets. Therefore, the null hypothesis which states that none of the stretching routines work more effectively in enhancing the participants' kicking performance cannot be rejected. Data revealed that both routines have equally enhanced the participants' kicking performance.

Discussion

Based on the data gathered, the following are the salient findings revealed in this study: after the stretching routines intervention, students in both groups improved in their kicking performance from "Needs Improvement" to "Good" description; sufficient data show that the students had marked improvement in their kicking performance and that significant differences were found in their performance after their exposures to both interventions; and even though Stretching Routine one had higher increment compared to Stretching Routine two, both stretching routines one and two show that the participants had comparatively enhanced kicking performance and level of flexibility.

The participants in both stretching routines groups showed improvement in their kicking performance and level of flexibility. Therefore, both the prescribed stretching routines one (Hamstring Stretch and Seat Straddle Lotus) and stretching routines two (Side Split and Seat Side Straddle) enhanced the kicking performance of student participants. According to Corbin et al. (2006), regular stretching exercises promote flexibility - a component of fitness- that permits freedom of movement, contributes to ease and economy of muscular effort, allows for successful performance in certain activities, and provides less susceptibility to some types of injuries or musculoskeletal problems.

The foregoing phenomenon could be in line with the participants' experience as espoused by Robbins (2009) who claimed that there are factors that affect their performance such as joint structure, soft tissues, inactivity, muscle temperature, age, genetics, gender, obesity, injury, and neutral factors. However, he further postulated that through regular stretching, the range of motion can be increased, and the person's level of tolerance is also enhanced (Hoeger & Hoeger 2014). Regular stretching can help people maintain good flexibility throughout life (Welk 2006).

These findings imply that the stretching routines one, the combination of Hamstring Stretch and Seat Straddle Lotus and stretching routines two, the Side-Split and Seat Side Straddle both equally facilitated the improvement of the flexibility of the kicking performance of the participant. As supported by Redmond (2008), people with greater flexibility have greater reach and it is one of the holy grails of Karate ability that will improve performance and increase resistance to injuries such as muscle and ligament tears. Thus, if participants continue to use these stretching routines, it implies greater improvement in their kicking performance whereas non-athletes may also use these routines to make every day activity involving flexibility easier to do. The continued examination of their skills must be accurate and dependable and must be given emphasis to identify little but significant changes brought on by exercise training (Chuang et al. 2021).

Conclusions

Based on the Findings, the following conclusions can be asserted. The researcher's assumption that the stretching routines such as Side Straddle Lotus, Hamstring Stretch, Seat Side Straddle and Side Split are effective in enhancing kicking performance is confirmed in the study. Both stretching routines have facilitated the improvement of the participants' kicking performance. Thus, if participants continue to use the stretching routines, there is a greater likelihood that they improve their kicking performance and that they can make every activity involving flexibility easier to do.

Corbin et al.'s (2006) postulation that regular stretching exercises promote flexibility – a component of fitness that permits freedom of movement and allows successful performance in certain activities is thus confirmed in this research undertaking.

Based on the findings and conclusions, the following recommendations are endorsed by the researcher. For the Physical Education Department, first, to ensure continuous and appropriate implementation and administration of the Physical Education Fitness program and Sports, particularly Karate-do and to determine the students' profile and their fitness level in order to give proper exercise programs which are fitted for their needs. Second, to provide more training to achieve maximum performance in sports and incorporate proper stretching combinations that will enhance the level of students' flexibility that can be used in class or at home or before and after exercises, sports and recreation. Finally, to emphasize proper stretching combinations that will enhance the level of flexibility of the students to prevent injuries before and after games and class tournament.

School Administrators are recommended to provide the students with appropriate venues for the development of their flexibility skills. Sport Coaches and trainers are also recommended to apply correct Strength and Conditioning programs to prepare the athletes/varsity players in their future games and tournaments. Finally, future researchers are urged to use findings of this study as baseline data to explore further experimental research that aims to measure other skill and health related components such as balance, agility, speed, power, coordination, reaction time, cardiovascular endurance, body composition, abdominal strength and endurance, arms strength and endurance.

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Athens Journal of Sports - Volume 11, Issue 3, September 2024 – Pages 179-192

Geographical Distribution of Small Physical Exercise Enterprises in the Greater Athens Area

By Gregory T. Papanikos[*]

The determinants of the geographical distribution of private business exercise centers in a large city, such as the wider area of Athens known as Attica, are the subject matter of this paper. The spatial distribution of any business enterprise, particularly those dealing with physical exercise, is of interest for two reasons. First, the spatial distribution of such businesses highlights the unevenness of health-related activities among the wider population living in a large metropolitan city, where geographical location often indicates uneven wealth distribution. This has certain government policy implications if physical exercise is to be considered a public good to be shared equally by all, rich and poor. Second, the spatial distribution of gym businesses shows whether, given wealth and population, there is an over- or undersupply of gym services. If there is an undersupply, there are opportunities for investment in small physical exercise businesses. This empirical study uses the 58 municipalities of Attica and the geographical distribution of 214 physical exercise businesses to show how wealth and population affect the under- or oversupply of physical exercise enterprises. The empirical evidence shows that, as expected, there is a positive effect of both wealth and population. However, the population effect is linear, while the wealth effect is non-linear; an increase in wealth increases the number of gyms in an area but at a decreasing rate. The study also identifies unexplored opportunities for investing in small physical exercise enterprises as well as areas of oversupply.

Keywords: *Gyms, population, wealth, SMEs, fitness centers, exercise, geographical distribution, spatial distribution, entrepreneurs, Athens, Attica*

Introduction

The analysis of the geographical distribution of private business exercise centers in a large city is of interest to society at large, as well as to individual entrepreneurs, usually small entrepreneurs, who want to invest in the business of providing exercise services. At the social level, the spatial distribution of private gyms is an indicator of the unequal distribution of wealth. Wealthy areas have more and better fitness centers than areas with less wealth. This is because wealthy people demand exercise services and can afford to consume them. Physical exercise is a good that has social benefits, such as promoting public health and increasing productivity.[1] The public health aspect can be viewed as a preventive

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[1]Actually, the whole literature of sports relates significantly to promoting physical exercise among the entire population, especially the youth. This is, for example, the legacy of the Olympic Games, as explained in Papanikos (2020 & 2022). Numerous other studies also link sports to physical exercise and various related issues. Refer, for example, to studies by Naquin et al. (2018),

health policy that reduces the cost of providing hospital and pharmaceutical services. The productivity aspect relates to an overall increase in income at both the individual and aggregate levels.

At the business level, particularly for Small and Medium Enterprises (SMEs), the spatial analysis will reveal which areas have more or fewer gym enterprises than needed, as determined by characteristics such as population and wealth. Areas with fewer gyms offer potential investment opportunities.

This study serves both these purposes. The wider area of Athens, called Attica, is used as a case study to demonstrate how this approach can be applied to test the hypothesis of the wealth effect on the number of gyms in a section of the city. Attica is one of the 13 regions of Greece and is divided into sections, which are further divided into municipalities called "dimoi" (δήμοι) in Greek, from which the word "democracy" originates.

In addition to wealth, the demand for fitness services depends on population size. Larger populations have a ceteris paribus positive effect on the demand for fitness services. I have examined this aspect in Papanikos (2015a).

At the business level, the results of this study can be used to divide the different municipalities of Attica into three groups. The first group consists of areas where there is an oversupply of gyms, which therefore do not offer opportunities for new investments. The second group includes areas where there is an undersupply of services, consequently providing an opportunity for new small firms to enter the market. Finally, the last group of municipalities consists of areas where the demand equals the supply of gyms.

A note of caution should be made at the outset. We assume that the gyms are very small firms that approximately supply the same quantity of services. While this is not a very strong assumption, it should nevertheless be mentioned. Measuring the actual output of each fitness service would have been a Herculean task, i.e., almost impossible. There are many reasons for this, but the most important is that most SMEs in Greece do not report their actual revenues to avoid paying taxes. This is a general phenomenon, as I have analyzed in a series of papers (refer to Papanikos 2024, 2015b).

This study is organized into six sections, including this introduction. Section two presents the municipalities of Attica (the wider area of Athens) divided into geographical sections, followed by the number of gyms in Attica presented per geographical section. Section three examines more closely the descriptive statistics of the two most important determinants of the number of business physical exercise enterprises in the wider area of Athens, namely the wealth of each municipality and its population. Wealth is measured by the average value of property in each of the municipalities, as property values vary across and within municipalities. Section four develops a simple model of the determinants of the number of SMEs in physical exercise services, which is then tested using cross-sectional data from the 58 municipalities of Athens. The raw data used and their sources are given in an appendix at the end of the paper. Section five uses the empirical findings (specifically the residual of the regression estimation) to

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Balatoni et al. (2020), Burke et al. (2014), Djafarova & Thompson (2020), Jedlicka & Predel (2018), and Máté (2018).

classify the 58 municipalities of the wider area of Athens into the three types mentioned above. The final section of the paper concludes.

The Gyms of Attica

As shown in Map 1, Greece is divided into 13 regions (municipalities – δήμοι). The region of Attica is further divided into 7 sections (units). It includes islands which from an economic analysis point of view cannot be considered as belonging to the same geographical area. They are included in the region of Attica for public administration reasons. This is why they are excluded from the analysis of this study. Attica in terms of area is the smallest region of Greece but almost half of the population of Greece lives and works in this region.

Map 1. *The 13 Regions of Greece*

Greece is divided into 332 municipalities (δήμοι), of which 58 belong to the area of Attica, excluding the islands. The distribution of the 58 municipalities across the six geographical sections of Attica is displayed in Figure 1. The central section of Athens has eight municipalities, including the city of Athens, which has a disproportionately higher population and density. The western section has the largest number of municipalities (15), followed by the eastern section of Attica (13). The northern section has 12 municipalities. The smallest sections, in terms of the number of municipalities, are Dytiki (Attica) and Piraeus.

This geographical division of the region of Attica has its own merit for the empirical analysis in this study. The sections may have different characteristics that are non-measurable, and the only way to account for such section-related effects is by using a dummy variable. As it turns out, and as discussed later in the empirical section of the paper, the central and eastern sections of Attica have a statistically significant effect on the number of gyms located in these two areas. Dummy variables to account for the effects of the other sections were not statistically significant.

The key variable of this study is the number of gyms in the region of Attica. The source of the data is provided in the appendix at the end of the paper. In total, there are 214 gyms. Figure 2 shows how these gyms are spatially distributed across the six geographical sections of the region of Attica. The central section of Athens has 42 gyms. Although it is the most populous of the six sections, the West of Attica has the highest number of gyms, with 56, followed by the North with 52. The East has 24 gyms, Piraeus has 18, and Dytiki Attica has 10.

Figure 1. *Municipalities (Δήμοι) per Geographical Section of Attica*

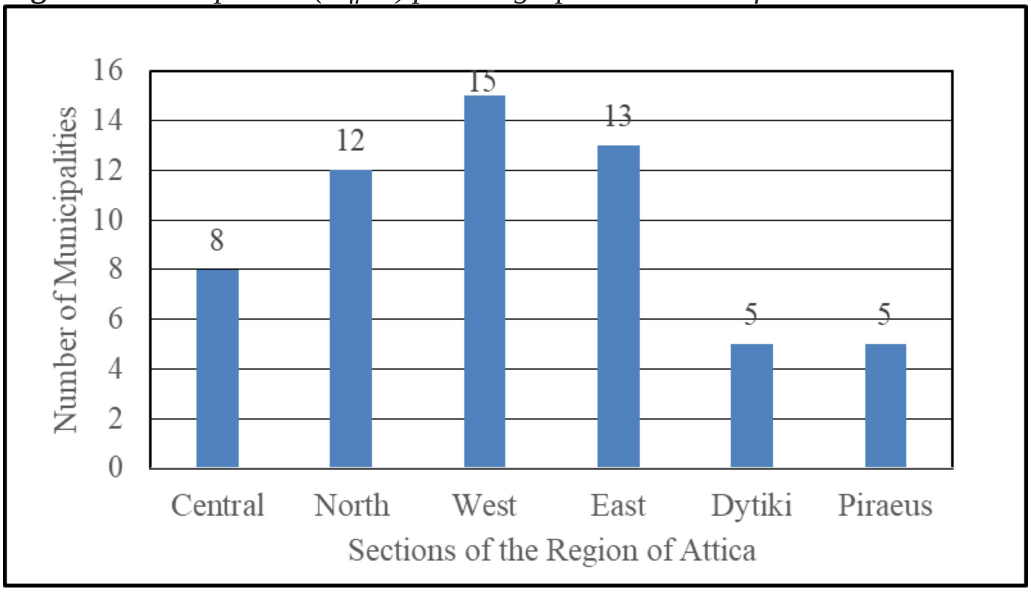
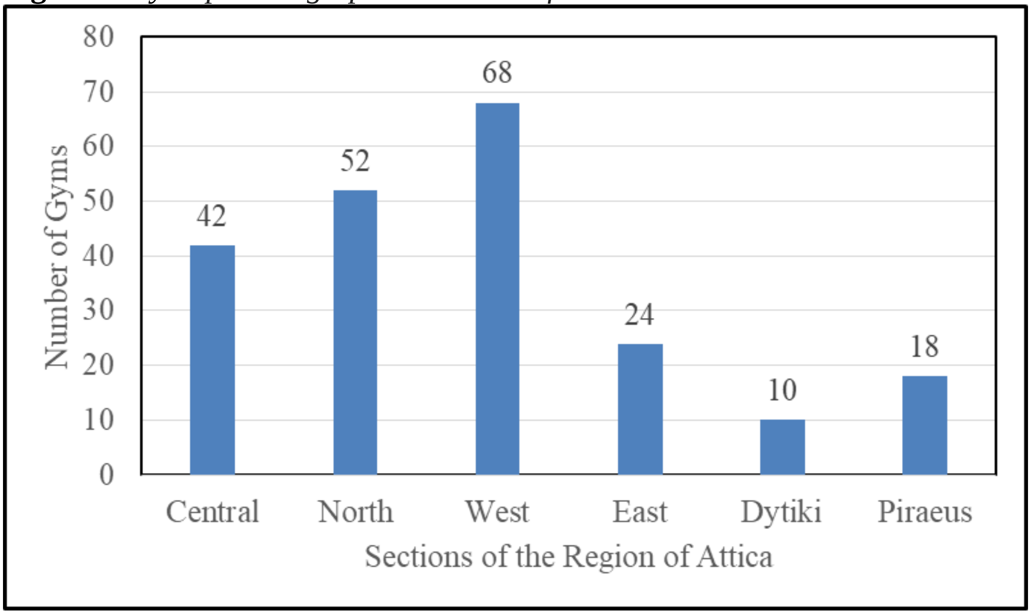


Figure 2. *Gyms per Geographical Section of Attica*



The variations in the number of gyms may be explained by differences in wealth and population. These two factors are examined in the next section and are used in the estimation of a regression equation as explanatory variables in the subsequent section of the paper.

Uneven Distribution of Wealth and Population

The most important variables for the purposes of this study are population and wealth. The raw data and their sources are provided in the appendix of this study. According to the 2021 Greek census data, the population of Greece was 10,482 million. In Attica, there were 3,744 million people, accounting for 36% of the Greek population. The actual number is much larger because many Greeks are registered in their hometowns for the census but live and work in Athens.

Table 1 reports descriptive statistics of population, population density (population divided by area), and property values of the 58 municipalities of Attica. The average population of the 58 municipalities is 56 thousand people, but there are significant variations. The city of Athens has 626 thousand people (the maximum value in the data set), while the smallest municipality, located in the Dytiki section, has 18 thousand people. The standard deviation is 83 thousand people. An important relevant indicator is density, defined as the number of people living in a square kilometer, as shown in the third column of Table 1. This is also an indicator of free space that may exist in an area where people can walk and play. These areas likely have small and large public parks and other amenities for outdoor activities, which might be considered substitutes for private fitness centers.

Table 1. *Summary Statistics of Property Values and Population*

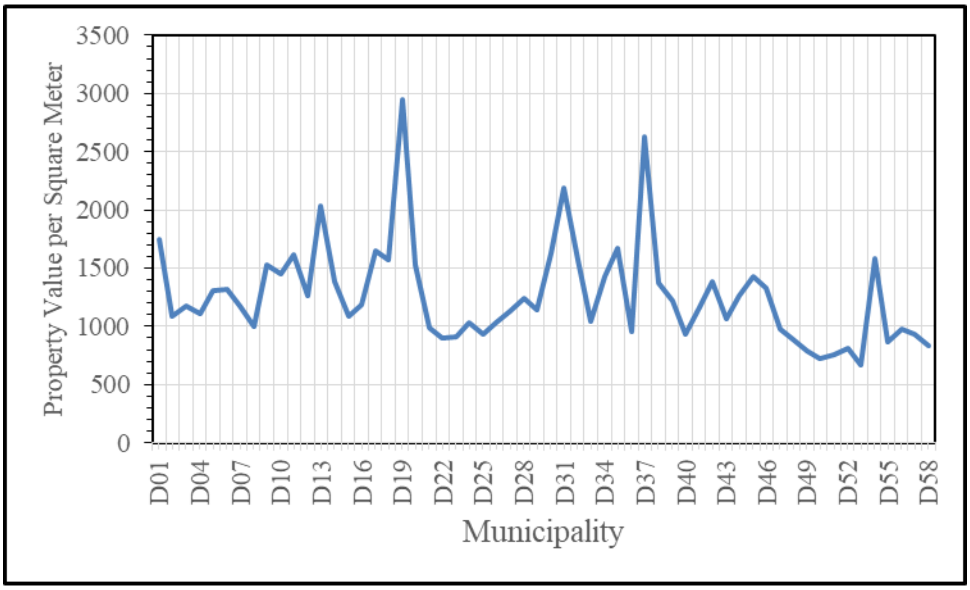
	Population (N) (000s)	**Density** (000s/km^2)	**Property Values (V)** (€/m^2)
Mean	65	6.44	1268
Median	49	6.12	1173
Standard Deviation	83	5.74	432
Range	626	20.77	2283
Minimum	18	0.04	664
Maximum	643	20.82	2948
Sum	3744		
Count	58	58	58

The last column of Table 1 provides the summary statistics of property values in each municipality. The data are reported by the government for administrative purposes such as property taxes. Although it is not the market price, it can be considered that the variations between the values reported by government officials are similar to those determined in the market.

A second issue is that each municipality does not have only one value for property. Within a municipality, there are multiple values. The table reports the average property values for each municipality. These average values are used as an explanatory measure of wealth.

The standard deviation of this measure, calculated for the 58 average property values, indicates wealth distribution among municipalities. The maximum, minimum, and range also illustrate the uneven distribution of wealth. Figure 3 shows this distribution for the entire range of 58 values.

Figure 3. *Distribution of Property Values*



It is obvious that wealth is not equally distributed. Four municipalities have an average property value of more than 2000 euros per square meter. Eighteen municipalities have a property value of less than 1000 euros. The remaining 36 municipalities have an average property value between 1000 and 2000 euros.

It should be noted that property values reflect other characteristics of the residents of these municipalities. Property value is a good approximation of the level of education and, consequently, people's awareness of the benefits of regular exercise in a gym.

The next section uses the two variables of population and property values in an empirical regression model to test whether these variables determine the number of gyms in each municipality of the region of Attica.

Estimation of the Population and Wealth Effects

The empirical model of the simple regression is given by the following general mathematical function:

(1) $G = F(N, V, \mathbf{D})$

Where:

F: Functional form, e.g., linear, polynomial, logarithmic, etc.
G: Number of gyms in the wider area of Athens
V: Wealth of the area of the gym
N: Number of people (population) living in the municipality of the gym
D: A vector of other variables, mainly dummy variables to account for various characteristics of the area, such as the section of the wider area of Athens, public transportation, etc.

For empirical purposes, the above equation can take many functional forms, but the one chosen to report here is a second-degree polynomial. Thus, the equation that is estimated is the following:

(2) $$G = a_0 + a_1N + a_2N^2 + a_3V + a_4V^2 + z\mathbf{D} + u$$

Where a's and z's are parameters to be estimated and u is the disturbance term of the regression which becomes the error term of the estimated equation. As shown in the next section, this error term is very important in determining the oversupply or undersupply of gyms in various administrative units (municipalities) of the wider area of Athens.

The polynomial functional form encapsulates several hypotheses that can be tested, which cannot be addressed by other forms such as the logarithmic form, for example. The logarithmic form assumes constant elasticity, which may not hold true. In the polynomial case, elasticity can vary according to the levels of the explanatory variables. In this scenario, the elasticity is given by:

(3) $$E_{GN} = (a_1 + 2a_2N)(N/G)$$

(4) $$E_{GV} = (a_3 + 2a_4V)(V/G)$$

The marginal impact of population and property values is given by:

(5) $$M_{GN} = a_1 + 2a_2N$$

(6) $$M_{GV} = a_3 + 2a_3N$$

The elasticity and the marginal effect vary with the explanatory variables, which is crucial for obtaining accurate effects at the municipality level, considering specific wealth and population characteristics.

Table 2 reports the regression results of the parameter estimates for equation (2) above. The table includes only the statistically significant dummy variables. Specifically, the dummy variables for Central and East were found to be statistically significant. The presence of a metro station in each municipality turned out to be marginally statistically significant.

Overall, Table 2 presents three estimated equations. The first regression includes the population variable (linear and squared), the property value variable (linear and squared), and three dummy variables: Central, East, and metro. The dummy variables Central and East take the value of one if the gym is located in the central or east section respectively, and zero otherwise. Similarly, the metro variable takes the value of one if there is a metro station close by, and zero otherwise. Two variables were found to be not statistically significant: population squared and metro. The non-significance of population squared suggests that the effect of population on the number of gyms is linear, indicating that as population increases, there is a proportional increase in the number of gyms.

In the second regression, the squared of population is dropped. Now, the variable metro is statistically significant at the 8.24% level of significance. The effect of metro is negative. One possible interpretation could be that people in this municipality have the option to use the metro to access gyms located farther away from their area. However, this explanation may not suffice because people from outside the municipality also find it convenient to travel and use gym services. Another explanation could be that the cost of renting property to establish a gym is higher in municipalities served by a metro compared to those without, which might weaken the effect. These two explanations together suggest that the effect of metro is not as strong as the other variables.

Table 2. *Regression Results* (Dependent variable: Number of gyms per municipality in the wider area of Athens)

	1	2	3
Constant	-4.25 (1.38)	-4.44 0.002	-4.00 (1.52)
Population (N)	0.035 (0.012)	0.042 (0.002)	0.04 (0.002)
Population (squared)	1.09E-05 (1.79E-05)	---	---
Property Value	0.008 (0.002)	0.008 (0.002)	0.0066 (0.002)
Property Value (squared)	-1.95E-06 (5.46E-07)	-1.90E-06 (5.20E-07)	-1.55E-06 (5.81E-07)
Central	-2.03 (0.59)	-1.95 (0.59)	-1.57 (0.66)
East	-1.92 (0.4)	-1.84 (0.42)	-1.4 (0.39)
Metro	-0.82 (0.57)	-0.90 (0.50)	---
R-squared	0.8441	0.8427	0.8350
R-squared (Adj.)	0.8223	0.8242	0.8192
F-statistic	38.68	45.54	52.64
Observations	58	58	58

Notes: In brackets, HAC standard errors.

The last regression equation excludes the metro variable. This regression estimation is used throughout the remainder of this section and the following sections of the paper. All variables are statistically significant, at least at the 2% level of significance, as indicated by the t-statistic.

Overall, the variations in explanatory variables explain at least 81.92% of the variance in the number of gyms among the 58 municipalities of Attica. For cross-sectional data, this coefficient of determination is quite high, but it should be noted that this is not a sample of gyms; it includes all gyms listed in the wider area of Athens (Attica). The F-statistic is also statistically significant, indicating that all estimated coefficients as a group have a significant effect on the dependent variable, i.e., the number of gyms.

As mentioned earlier, population has a linear effect on the number of gyms, while population squared is not statistically significant. In this case, the population elasticity of gyms drops to the following:

(7) $$E_{GN} = (a_1)(N/G)$$

Evaluating this at the average values of N (64.55) and G (3.69), then the elasticity is equal to:

$$E_{GN} = (0.0406)*(3.69/64.55) = 0.0023$$

This implies that a 10% increase in the population of a municipality will increase the number of gyms by 0.023%.

The effect of property values is non-linear. A rise in property values increases the number of gyms but at a decreasing rate. Evaluating the elasticity at the mean values of G (3.69) and V (1268).

$$E_{GV} = (0.0066 + 3.10E\text{-}06*1268.43)*(344) = 3.62$$

This implies that a 10% increase in property values of a municipality will increase the number of gyms by 3.62%.

All three dummy variables have a negative effect. On average, municipalities that are located in the Central and East sections of the Region of Attica have fewer gyms than the rest of the Attica sections.

Opportunities to Invest in Private Gyms

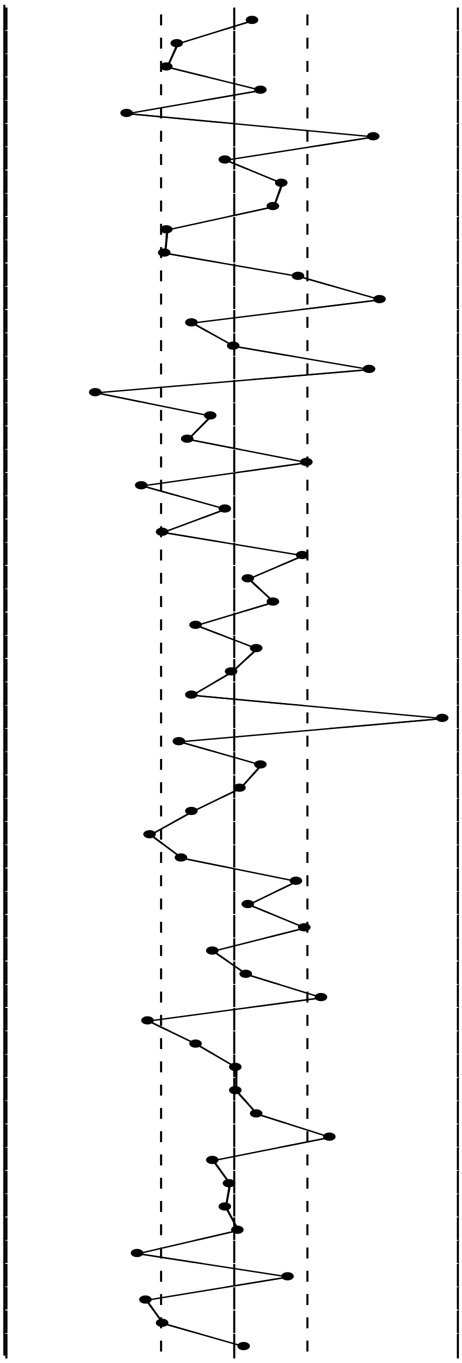
The evidence presented in the previous section can be used to identify municipalities in Attika that have fewer gyms than predicted by the estimation. The residuals follow a normal distribution. The Jarque-Bera test rejects the hypothesis of non-normality.

Table 3 presents the actual, fitted, and residual values from the regression of the third model in Table 2. A negative (positive) difference between the fitted and actual values indicates an undersupply (oversupply) of gyms in that specific municipality.

Table 3. *Regression Residuals*

obs	Actual	Fitted	Residual
1	28.0000	27.5567	0.44332
2	1.00000	2.28702	-1.28702
3	1.00000	2.50823	-1.50823
4	1.00000	0.37310	0.62690
5	1.00000	3.43438	-2.43438
6	7.00000	3.75100	3.24900
7	1.00000	1.18816	-0.18816
8	2.00000	0.90144	1.09856
9	6.00000	5.08406	0.91594
10	3.00000	4.51474	-1.51474
11	2.00000	3.58358	-1.58358
12	5.00000	3.53181	1.46819
13	9.00000	5.62957	3.37043
14	3.00000	3.94377	-0.94377
15	3.00000	3.01442	-0.01442
16	7.00000	3.88441	3.11559
17	1.00000	4.17609	-3.17609
18	4.00000	4.54748	-0.54748
19	2.00000	3.06397	-1.06397
20	7.00000	5.30026	1.69974
21	4.00000	6.08584	-2.08584
22	1.00000	1.21629	-0.21629
23	2.00000	3.60478	-1.60478
24	5.00000	3.39333	1.60667
25	5.00000	4.68205	0.31795
26	5.00000	4.05439	0.94561
27	3.00000	3.87045	-0.87045
28	6.00000	5.47295	0.52705
29	4.00000	4.03115	-0.03115
30	4.00000	4.95287	-0.95287
31	12.0000	7.19322	4.80678
32	3.00000	4.24403	-1.24403
33	3.00000	2.32875	0.67125
34	6.00000	5.81808	0.18192
35	5.00000	5.93510	-0.93510
36	2.00000	3.94980	-1.94980
37	2.00000	3.18264	-1.18264
38	4.00000	2.54848	1.45152
39	2.00000	1.63366	0.36634
40	2.00000	0.36229	1.63771
41	1.00000	1.46453	-0.46453
42	2.00000	1.72560	0.27440
43	3.00000	0.98381	2.01619
44	1.00000	2.96518	-1.96518
45	1.00000	1.84723	-0.84723
46	2.00000	1.93212	0.06788
47	1.00000	0.96071	0.03929
48	1.00000	0.44396	0.55604
49	4.00000	1.77461	2.22539
50	1.00000	1.51564	-0.51564
51	1.00000	1.09187	-0.09187
52	2.00000	2.21921	-0.21921
53	2.00000	1.89115	0.10885
54	7.00000	9.24781	-2.24781
55	5.00000	3.73901	1.26099
56	1.00000	3.00783	-2.00783
57	3.00000	4.59872	-1.59872
58	2.00000	1.75674	0.24326

Residual Plot



The first observation corresponds to what is called the city of Athens, which has the highest population. The actual number of gyms is 28. The number estimated by the regression is 27.6, and rounding to the closest integer gives a fitted number of 28. Thus, in the city of Athens, the existing number of gyms is optimal, as there is neither oversupply nor undersupply.

The second municipality, as seen in the table in the appendix, is called Vironas (Βύρωνας), located very close to the City of Athens. According to the estimations, this municipality could support 2 gyms, but there is only one. If we define undersupply as a difference between fitted and actual numbers greater than two, indicating a need for at least two more gyms, then Table 3 shows that there are 6 municipalities where there was an undersupply of gyms. This represents 10% of the total. Similarly, there is a 10% oversupply of gyms, which is not surprising given that the error terms are normally distributed. The remaining municipalities can be considered to have an optimal number of gyms.

Conclusions

The main findings of this study can be summarized as follows. First, the vast majority of the 58 municipalities in Attica (about 80%) have an appropriate number of private gyms, considering the variation in population and property values (wealth). There is significant variability in both population and wealth, which is reflected in the number of private gyms present in each municipality.

However, approximately 10% of municipalities show potential for profitable investment in new gyms. Conversely, another 10% exhibit an apparent oversupply of private gyms. It is important to interpret this evidence cautiously because there may be other local characteristics that could explain deviations from what the data suggests as the optimal number of gyms.

Acknowledgments

This paper was presented at the *20th Annual International Conference on Sport & Exercise Science, 29-30 July 2024, Athens, Greece* by the Sports Unit of the Athens Institute. I would like to thank two anonymous referees for their constructive comments and suggestions.

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Appendix A1. *Raw Data and Sources (only the statistically significant variables)*

Dimos	Dimos	G	N	V	Central	East	Metro
Αθηναίων	D1	28	643.45	1750	1	0	1
Βύρωνος	D2	1	59.13	1092	1	0	0
Γαλατσίου	D3	1	57.91	1171	1	0	0
Δάφνης - Υμηττού	D4	1	33.89	1106	1	0	1
Ζωγράφου	D5	1	69.87	1310	1	0	0
Ηλιουπόλεως	D6	7	76.73	1320	1	0	0
Καισαριανής	D7	1	26.27	1175	1	0	0
Νέας Φιλαδέλφειας - Νέας Χαλκηδόνος	D8	2	34.96	995	1	0	0
Αμαρουσίου	D9	6	71.83	1527	0	0	1
Αγίας Παρασκευής	D10	3	62.15	1450	0	0	1
Βριλησσίων	D11	2	32.42	1617	0	0	1
Ηρακλείου	D12	5	50.49	1261	0	0	1
Κηφισιάς	D13	9	72.88	2032	0	0	1
Λυκόβρυσης-Πεύκης	D14	3	31.00	1383	0	0	0
Μεταμορφώσεως	D15	3	30.17	1090	0	0	0
Νέας Ιωνίας	D16	7	64.61	1183	0	0	1
Παπάγου-Χολαργού	D17	1	45.27	1650	0	0	1
Πεντέλης	D18	4	35.61	1575	0	0	0
Φιλοθέης-Ψυχικού	D19	2	27.64	2948	0	0	0
Χαλανδρίου	D20	7	77.10	1524	0	0	1
Περιστερίου	D21	4	133.63	988	0	0	1
Αγίας Βαρβάρας	D22	1	26.76	900	0	0	1
Αγίων Αναργύρων - Καματερού	D23	2	61.46	906	0	0	0
Αιγάλεω	D24	5	65.83	1030	0	0	1
Ιλίου	D25	5	84.00	936	0	0	0
Πετρουπόλεως	D26	5	60.15	1030	0	0	0
Χαϊδαρίου	D27	3	47.05	1131	0	0	0
Καλλιθέας	D28	6	97.62	1246	0	0	1
Αγίου Δημητρίου	D29	4	71.66	1138	0	0	1
Αλίμου	D30	4	43.17	1627	0	0	0
Γλυφάδας	D31	12	89.60	2189	0	0	0
Ελληνικού-Αργυρούπολης	D32	3	50.03	1569	0	0	1
Μοσχάτου-Ταύρου	D33	3	39.66	1040	0	0	1
Νέας Σμύρνης	D34	6	72.85	1429	0	0	0
Παλαιού Φαλήρου	D35	5	64.86	1673	0	0	0
Αχαρνών	D36	2	108.17	958	0	1	0

Βάρης - Βούλας - Βουλιαγμένης	D37	2	52.55	2626	0	1	0
Διονύσου	D38	4	42.38	1370	0	1	0
Κρωπίας	D39	2	30.82	1219	0	1	0
Λαυρεωτικής	D40	2	25.20	936	0	1	0
Μαραθώνος	D41	1	31.33	1160	0	1	0
Μαρκόπουλου Μεσογαίας	D42	2	21.72	1389	0	1	0
Παιανίας	D43	3	28.04	1063	0	1	0
Παλλήνης	D44	1	59.46	1260	0	1	0
Ραφήνας-Πικερμίου	D45	1	22.33	1429	0	1	0
Σαρωνικού	D46	2	30.05	1333	0	1	0
Σπάτων-Αρτέμιδος	D47	1	34.92	982	0	1	0
Ωρωπού	D48	1	31.81	890	0	1	0
Ελευσίνας	D49	4	30.15	793	0	0	0
Ασπροπύργου	D50	1	31.38	729	0	0	0
Μάνδρας-Ειδυλλίας	D51	1	17.82	759	0	0	0
Μεγαρέων	D52	2	38.03	817	0	0	0
Φυλής	D53	2	48.16	664	0	0	0
Πειραιώς	D54	7	168.15	1584	0	0	1
Κερατσινίου - Δραπετσώνας	D55	5	89.54	872	0	0	1
Κορυδαλλού	D56	1	61.25	981	0	0	1
Νίκαιας - Αγίου Ιωάννη Ρέντη	D57	3	103.49	935	0	0	1
Περάματος	D58	2	25.63	830	0	0	0

Where:

G: The number of gyms. Two sources of data were used. First, gyms in Attica are listed in https://www.vrisko.gr/dir/gymnastiria/ which is a website that promotes the services of the fitness centers. They are listed for free. The second source is the official website of the Union of Owners of Gyms in Attica (https://siga.gr/). There is a third source from official government archives (Region of Attica) but it is outdated. From the two the first was considered as more reliable. For example, the second list showed municipalities of Attica with zero gyms when there were some. The reason is that the second list includes only those who are members of the union.

N: population from the Greek census of 2021.

V: The wealth of each of the 58 municipalities was calculated as the average value of the properties of each one as this is determined by the government for property taxes.

Central: Takes the value of one if the municipality is located in the central section of Attica and zero otherwise.

East: Takes the value of one if the municipality is located in the east section of Attica and zero otherwise.

Metro: Takes the value of one if the municipality is located close to a metro station and zero otherwise.