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SPORT RETAIL AND ECONOMIC RESILIENCE: LOGISTICS AND SUPPLY CHAIN PERSPECTIVES

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Abstract.

This study addressed the determinants of performance and competitiveness in independent sporting goods retail, with a particular focus on digitalisation, sustainability, innovation, and risk management practices. Unlike prior research that mainly examined large multinational chains, the article provided original insights into resource-constrained retailers, highlighting how organisational readiness was shaped by structural and managerial factors. The objective was to evaluate the effects of these practices on sales performance, supply stability, and local competitive positioning. Data were collected through a structured questionnaire applied to 461 independent retailers of sporting goods, sports apparel, and sports footwear across Romania. An Ordered Logit Model (OLM) was employed to analyse the relationships between explanatory constructs and performance outcomes. The findings revealed that digitalisation and risk management significantly improved sales and supply stability, while innovation and green logistics primarily enhanced competitiveness. The article contributed theoretically by linking resilience and sustainability debates to small-scale retail contexts and practically by offering actionable recommendations for managers and policymakers.

Keywords: economic resilience, logistics, supply chain, sport retail.

JEL Classification: C25, F18, L81.

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Introduction

Independent sporting goods retailers operate today in a context marked by rapid transformations in supply chains, where digitalisation, sustainability, and risk management practices are increasingly viewed as critical levers for competitiveness. Unlike large multinational chains, small stores often lack integrated systems and financial resources, which constrains their ability to adopt advanced practices and sustain long-term resilience. This raises important questions about how organisational readiness is shaped by structural factors and managerial choices in resource-limited retail environments (Mukonza & Swarts, 2019).

From a theoretical perspective, the literature identifies logistics digitalisation, green logistics, and risk management maturity as essential elements of supply chain resilience. Digital tools enhance visibility, coordination, and efficiency, supporting better alignment of supply and demand (Qian et al., 2019). At the same time, sustainable practices such as decarbonisation or reverse logistics contribute not only to environmental performance, but also to financial outcomes and customer loyalty (Frei et al., 2020, Prodea et al., 2025). However, empirical findings in small-scale retail suggest that adoption remains incremental and fragmented, with sustainability often limited to packaging choices rather than integrated supply chain redesign (Fuchs & Hovemann, 2022).

The Romanian sporting goods retail sector provides a relevant setting to explore these dynamics. According to survey data, the average store employs just over six workers, operates on a sales area of about 128 m², and has been in business for roughly 10.5 years. In terms of performance outcomes, 60.6% of respondents rate their supply conditions as stable or very stable, reflecting relatively solid sourcing practices. Yet, only 22.4% of stores perceive themselves as more competitive than their local rivals, and sales performance remains concentrated around "medium" levels, with just 10% reporting very high performance. These figures underline a paradox: while operational stability is largely achieved, translating it into market differentiation proves significantly more difficult.

This paper addresses this gap by evaluating the determinants of sales performance, supply stability, and competitive position through four explanatory dimensions: logistics digitalisation, decarbonisation, innovation orientation, and risk management maturity. The study employs an Ordered Logit Model (OLM) to test their effects on a dataset of 461 valid responses from independent sporting goods retailers across all Romanian counties. The results not only theoretically contribute to discussions on resilience and sustainability in fragmented supply chains, but also offer practical insights for managers and policymakers seeking to strengthen competitiveness in small-scale retail.

The remainder of the article is structured as follows. Section 1 reviews the existing literature, highlighting theoretical perspectives and empirical findings on digitalisation, green logistics, risk management, and specific retail supply chain challenges. Section 2 outlines the research methodology, including data collection, construct operationalisation, and the econometric model. Section 3 presents and interprets empirical results, linking them to prior studies, and discussing implications. Finally, the Conclusions section summarises the contributions of the study and outlines recommendations for both practitioners and future research.

1. Literature review

To ensure clarity and coherence, this literature review is structured into thematic sections, each addressing a specific dimension of supply chains in sporting goods retail. Such an organisation goes beyond a simple listing of contributions by enabling comparative analysis

between different approaches in the literature, as well as critical reflection on how they relate to our own findings. In this way, the review highlights both convergences and discrepancies between established theoretical frameworks and the practical realities observed, providing a solid foundation for interpreting our contributions. In contrast, our study of independent sporting goods retailers shows distinct patterns regarding these mechanisms, highlighting differences in resource constraints, adoption levels, and performance outcomes.

Digitalisation and innovation in logistics. Literature frequently positions digitalisation and innovation as transformative forces for supply chains, though the pathways and outcomes diverge significantly across contexts. For example, Ishfaq et al. (2021) argue that omnichannel retail thrives on network visibility and cognitive automation, yet our results suggest only moderate digital integration with suppliers, reflecting a slower and more fragmented trajectory in sporting goods retail. Similarly, while Zhao et al. (2023) demonstrate that digitalisation strengthens resilience by enhancing absorption, response, and recovery capabilities, the evidence from our dataset shows a different pattern: digital tools appear more closely tied to sales performance than to supply stability, pointing toward efficiency-driven adoption rather than systemic resilience. Collaboration emerges as another point of divergence. Li et al. (2023) emphasise that robustness depends on combining digitalisation with interorganisational collaboration; however, most independent stores in our survey lack the contractual structures or partner networks envisioned in such frameworks. A comparable gap arises in procurement: although Harju et al. (2023) highlight procurement digitalisation as a key resilience driver, our findings reveal that adoption remains fragmented, constrained by the limited resources of small retailers. From a broader process perspective, Lambert and Enz (2017) argue that true innovation rests on systemic process integration and collaboration. In contrast, our study shows piecemeal digital uptake—inventory management systems or isolated monitoring tools—rather than integrated solutions. Retail innovation trends also diverge: Pantano et al. (2017) identify patents in customer experience technologies as the fastest-growing innovations, whereas our stores rely more on delivery experimentation (e.g., click-and-collect), a sign of incremental and operational rather than experiential innovation. Similarly, while Albors-Garrigos (2020) stresses co-innovation with customers, our evidence points to a reactive orientation, with limited involvement of consumers in early innovation stages. Finally, real-time monitoring marks another contrast. Ishfaq's (2021) emphasis on real-time analytics assumes widespread adoption, yet only a minority of the surveyed stores monitor operational indicators continuously, leaving a gap between theory and practice. Overall, the literature tends to frame digitalisation as a pathway to resilience, collaboration, and strategic transformation, but our results suggest that in independent sporting goods retail innovation remains incremental, resource-bounded, and primarily targeted at operational improvements rather than at customer experience or systemic robustness. In contrast, our study of independent sporting goods retailers shows distinct patterns regarding these mechanisms, highlighting differences in resource constraints, adoption levels, and performance outcomes.

Decarbonisation and Sustainable Supply Chains. Decarbonisation is increasingly portrayed in the literature as both a regulatory obligation and a strategic lever for competitiveness, yet our evidence indicates that in independent sporting goods retail green practices remain at a formative and fragmented stage. For instance, Toktaş et al. (2024) stress that systemic decarbonisation in city logistics requires investments in electric fleets, drones, and advanced optimisation tools, but the modest average score of our DECARB construct reveals that such technologies are far beyond the reach of small retailers. Similarly, while Qian et al. (2019)

demonstrate that low-carbon initiatives simultaneously improve environmental and financial performance in logistics, our findings suggest that sporting goods retailers limit themselves to symbolic actions, mainly packaging adjustments, rather than integrated supply chain redesign. Barriers to circular economy adoption have also been highlighted. Fuchs and Hovemann (2022) point to inefficiencies in reverse logistics, a challenge that resonates with our observation that many stores do not even establish measurable emission-reduction targets, reflecting both structural and resource limitations. In the same vein, Frei et al. (2020) show how reverse logistics can enhance both sustainability and customer loyalty, yet our respondents rarely leverage product returns as a green strategy, leaving untapped potential. The literature further underscores the retailer's ecological influence: Yang et al. (2017) describe them as "gatekeepers" in shaping supplier and consumer behaviour, whereas in our dataset most stores appear to exercise little upstream influence, focusing instead on short-term cost and availability. The commercial dimension of green practices also reveals gaps. Mukonza and Swarts (2019) find that green marketing can simultaneously strengthen business performance and corporate image, but in our case, retailers seem to prioritise immediate competitiveness over sustainability branding, reducing long-term differentiation opportunities. Likewise, although Petljak et al. (2018) provide evidence that green logistics in food retail enhances resilience and economic outcomes, similar synergies remain largely underexploited in sporting goods logistics. Even more telling is the contrast with Zhao et al. (2023), who argue that digitalisation and sustainability are intertwined drivers of resilience: in our study, sustainability efforts remain secondary to digital investments and efficiency-oriented innovations. Taken together, while prior research highlights decarbonisation as a transformative force capable of delivering both operational and strategic benefits, our results show that in small-scale sporting goods retail environmental practices are incremental, compliance-driven, and often disconnected from broader competitiveness strategies. In contrast, our study of independent sporting goods retailers shows distinct patterns regarding these mechanisms, highlighting differences in resource constraints, adoption levels, and performance outcomes.

Supply Risk Management Maturity. In supply chain research, risk management is often conceptualised as a structured, multi-stage process of detection, assessment, mitigation, and monitoring. However, our findings reveal that in small sporting goods retail, these practices remain basic, relying mainly on redundancy and simple tools. For instance, Gurtu and Johny (2021) caution against one-size-fits-all frameworks, an observation that resonates with our evidence: most independent stores rely on alternative suppliers and safety stocks rather than sophisticated modelling or predictive systems. Similarly, DuHadway et al. (2017) distinguish between opportunistic risks and force majeure disruptions, but our respondents tend to prepare only for inadvertent risks, with little attention to intentional threats or formal contractual safeguards. Simulation-based approaches offer a more complex perspective. Lochan et al. (2021) demonstrate that ripple effects from supplier shutdowns can quickly erode revenues, underscoring the value of advanced optimisation strategies. In contrast, our sample reflects a simpler logic: stores mirror this finding only through the maintenance of safety stocks, confirming the importance of redundancy but not the sophistication of simulation-driven planning. While Shaikh and Ahmed (2022) emphasise trust and cooperation as enablers of adaptive resilience, our survey points to transactional and fragmented supplier relations that hinder the potential for relational risk management. Technology-enabled practices also illustrate a gap. Baryannis et al. (2018) argue that artificial intelligence can move SCRM from reactive to proactive modes, but our data show that small stores remain anchored in conventional contingency plans, without predictive analytics or

digital sensing. Even DuHadway's typology, which underlines tailored recovery strategies for different disruption types, contrasts with our evidence of generic, one-size-fits-all procedures lacking escalation criteria. Cross-firm alignment is another area of divergence. Lambert and Enz (2017) stress that process integration and systemic alignment are necessary to strengthen resilience. However, our findings indicate that even in the absence of such integration, small stores manage to achieve relatively stable supply, though at the cost of scalability and long-term robustness. On the governance side, Mamic (2005) documents how multinational sporting goods companies integrate Codes of Conduct as formalised risk mitigation, but this stands in stark contrast to the minimal codification observed among our respondents. Finally, Ciocoi-Pop et al. (2025) highlight the role of digitalisation in advancing sustainability reporting in sports organisations, indirectly pointing to the role of greater digital maturity in risk monitoring. By comparison, our stores lag significantly in this area, reflecting their limited capacity for digitally driven risk oversight. Overall, while the literature emphasises increasingly complex, technology-enabled, and collaborative approaches to supply risk management, our evidence shows that in small-scale sporting goods retail maturity is anchored in redundancy and basic continuity plans. This approach ensures short-term stability but falls short of the adaptive, proactive resilience envisioned in contemporary frameworks. In contrast, our study of independent sporting goods retailers shows distinct patterns regarding these mechanisms, highlighting differences in resource constraints, adoption levels, and performance outcomes.

Sporting Goods Supply Chains and Retail Specifics. The literature often highlights the unique features of sporting goods supply chains, but our findings highlight that independent stores operate with modest capabilities, diverging from the advanced frameworks described. For example, Roscoe and Baker (2014) emphasise that segmentation strategies must align consumer behaviour with retailer categories, moving beyond generic lean–agile models. Our evidence, however, shows that small stores compete mainly through local positioning and operational stability, lacking the analytical tools to implement sophisticated segmentation. Service quality and digital integration also appear uneven. Mao (2020) finds that retail quality in sporting goods depends strongly on customer service and digital solutions, but our dataset reveals a different emphasis: delivery model innovations such as click-and-collect are more advanced than service-related innovations, indicating an imbalance between operational and experiential improvements. Governance practices mark another sharp contrast. Mamic (2005) documents how multinational sports firms use Codes of Conduct to manage risk and sustainability, while our surveyed stores show little evidence of formal compliance structures, exposing the gulf between global and small-scale practices. Sustainability challenges add further divergence. Fuchs and Hovemann (2022) highlight reverse logistics inefficiencies and consumer awareness barriers in the outdoor sporting goods industry, but our results reveal an even earlier stage of adoption: many small shops avoid setting measurable environmental targets altogether. Mao (2020) also stresses that fragmented labour structures undermine competitiveness; our findings echo this, showing that with an average of only six employees, stores face structural limitations in adopting digital or sustainable practices. Dynamic alignment and competitive differentiation represent another gap. Roscoe and Baker's (2014) case of Adidas and Reebok illustrates how demand-supply alignment boosted market share, but our independent retailers rely on basic supply stability through supplier relationships, lacking the analytics to replicate such strategies. Similarly, although Frei et al. (2020) demonstrate that reverse supply chains can enhance customer loyalty, our respondents treat returns mainly as logistical costs, missing opportunities for

differentiation. From a consumer perspective, Hu et al. (2019) argue that CSR initiatives resonate more with customers than isolated green practices, which aligns with our observation that sustainability alone does not significantly strengthen competitiveness in small sporting goods retail. Taken together, Roscoe and Baker's (2014) conclusion that "one-size-fits-all" supply chains are obsolete is reinforced by our evidence: performance among independent retailers is highly heterogeneous, yet most stores remain unable to differentiate beyond average results. Overall, the literature depicts sporting goods supply chains as innovation-driven and strategically dynamic, whereas our findings suggest that small, specialised retailers continue to rely on modest digitalisation, incremental innovation, and fragmented sustainability practices, lagging far behind the systemic capabilities of multinational players. In contrast, our study of independent sporting goods retailers shows distinct patterns regarding these mechanisms, highlighting differences in resource constraints, adoption levels, and performance outcomes.

Research hypotheses derived from the literature review

The formulation of research hypotheses builds on the key insights synthesised in the literature review, linking digitalisation, sustainability, risk management, and innovation with sales performance, supply stability, and competitive positioning in sporting goods retail. These hypotheses are grounded in prior empirical evidence and theoretical arguments, aiming to capture the expected causal relationships that will be tested in the empirical analysis.

H1. Digitalisation positively influences sales performance in sporting retail goods. Digital tools improve visibility, coordination, and efficiency, enabling stores to better align supply and demand and increase revenue potential (Ishfaq et al., 2021). Prior research also shows that digitalisation enhances resilience and performance by strengthening absorptive and response capabilities (Zhao et al., 2023).

H2. Advanced supply risk management practices increase supply stability. Securing multiple suppliers, maintaining safety stocks, and developing contingency procedures reduce exposure to disruptions and help stabilise operations (Gurtu & Johny, 2021). Simulation studies also confirm that inventory buffers and redundancy mitigate ripple effects from supplier shutdowns (Lochan et al., 2021).

H3. Innovation orientation strengthens the competitive position in local markets. Introducing new products, experimenting with delivery models, and rapid testing of services are critical drivers of competitiveness in retail (Pantano et al., 2017). Co-innovation with customers further reduces risk and increases the relevance of innovations, improving differentiation (Albors-Garrigos, 2020).

H4. Decarbonisation and sustainable logistics practices enhance both supply stability and competitiveness. Adoption of green practices, such as reverse logistics or eco-friendly packaging, can improve operational resilience and reduce long-term risks (Fuchs & Hovemann, 2022). Evidence also suggests that low-carbon initiatives simultaneously improve environmental and financial outcomes for retailers and logistics providers (Qian et al., 2019).

H5. Innovation orientation contributes to greater supply stability. Innovative practices are expected to support adaptive and resilient supply systems by creating flexibility and responsiveness to disruptions (Lambert & Enz, 2017). Collaboration and process innovation, when combined with technology, have been shown to improve robustness under volatile conditions (Li et al., 2023).

2. Research methodology

The research objectives are to assess how digitalisation, decarbonisation, innovation orientation, and supply risk management maturity shape sales performance, supply stability, and competitive positioning in independent sporting goods retail. To address these objectives, the methodology relies on a structured survey administered to 461 retailers and constructs composite variables for each explanatory dimension using multi-item Likert-scale measures. An Ordered Logit Model is then employed to rigorously test the effects on the three performance outcomes, ensuring full alignment between the stated objectives and the empirical analytical design.

Data collection. The study investigates independent sporting goods, clothing, and footwear stores across all 41 counties of Romania, while large retail chains such as Decathlon or Hervis were deliberately excluded to avoid distortions caused by their dominant financial resources and integrated supply systems. The sample was constructed using a stratified random sampling procedure, based on regions and store types, with random selection of respondents within each stratum to minimise bias. A total of 600 questionnaires were distributed, of which 461 valid responses were obtained, corresponding to a response rate of 76.8%, a level considered high for organisational surveys. The data collection took place between March and May 2026, during which store representatives were contacted through a combined online and telephone-based administration procedure. The questionnaires were initially distributed via a dedicated online survey platform, and follow-up phone calls were conducted for stores that did not respond within two weeks, both to confirm eligibility and to facilitate completion of the research instrument. This standardised contact and verification protocol was designed to reduce nonresponse error and ensure that the respondents were individuals holding decision-making responsibilities within the stores. The sample was constructed through stratified random sampling by region and store type, with random selection of respondents within each stratum to minimise bias. In total, 600 questionnaires were distributed, yielding 461 valid responses, which represents a response rate of 76.8% and is considered high for organisational surveys. Of the final sample, 65.5% of stores are specialised and 34.5% are generalist, ensuring adequate representation of both categories. On average, stores employ about 6 workers and operate with a sales area of around 128 m², while their average age is 10.5 years, reflecting the typical scale and maturity of independent retailers. The Ordered Logit Model (OLM) was applied to estimate effects on three ordinal outcomes (sales performance, supply stability, and competitive position) each measured on a 1-5 Likert scale. By excluding large chains, the study captures the realities of smaller, resource-constrained businesses, where competitiveness depends primarily on local positioning and incremental improvements. The relatively high response rate and balanced representation of store types increase the robustness of the dataset and strengthen the generalisability of the findings. The questionnaire was directed at store owners and managers, who are responsible for strategic decisions on suppliers, innovation, and sustainability. To ensure comparability of responses, participants received clear explanations of the survey items, including the interpretation of the seven-point scales used for constructs such as digitalisation, innovation, decarbonisation, and risk management.

Definition of constructs and variables. The study investigates factors shaping performance and competitiveness in independent sporting goods retail through dependent and explanatory variables. The dependent variables assess sales performance (SALES_LEVEL), supply stability (SUPPLY_STAB), and local competitive position (COMP_POS). Explanatory variables capture store-level practices: logistics digitalisation (DIGI), reflecting the use of

digital tools for inventory, supplier integration, and monitoring; green logistics orientation (DECARB), capturing transport optimisation, low-impact packaging, and emission reduction targets; innovation orientation (INOV), defined by new product introduction, delivery model experimentation, and rapid testing; and supply risk management maturity (RISK), measuring alternative sourcing, safety stocks, and disruption procedures. Control variables describe structural characteristics of the stores, including type of store (STORE_TYPE), number of employees (EMP_TOTAL), store age (STORE_AGE), and sales area (SALES_AREA). Table 1 and Table 2 provide a detailed overview of these variables and their descriptive statistics.

Table 1: Main variables of the study and their descriptive statistics

Code	Description	Summary descriptive statistics
Dependent variables		
SALES_LEVEL	Current Sales Level. How do you assess the current level of your store's sales compared to the economic potential you have (positioning, investments made, sales area, etc.)?	1 (Very Low): 6,7% 2 (Low): 21,5% 3 (Medium): 37,1% 4 (High): 24,7% 5 (Very High): 10,0%
SUPPLY_STAB	Supply Stability. How would you rate the stability of your store's supply (availability of necessary products, absence of disruptions)?	1 (Very Unstable): 4,1% 2 (Unstable): 7,8% 3 (Neither Stable/Unstable): 27,5% 4 (Stable): 40.6% 5 (Very Stable): 20,0%
COMP_POS	Local Competitive Position. How would you rate your store's competitiveness compared to other similar stores in the area?	1 (Much Below Competitors): 8,0% 2 (Below Competitors): 32,8% 3 (At the Same Level): 36,4% 4 (Above Competitors): 18,7% 5 (Much Above Competitors): 3,7%
Key explanatory variables		
DIGI	Level of Logistics Digitalisation reflects the use of digital tools for inventory management, supplier integration, and real-time monitoring of operational indicators (mean of DIGI1–DIGI3, Cronbach's alpha = 0.738).	Mean: 3.92 St.dev.: 1.31 Min: 1 Max: 7
DECARB	Decarbonisation & Green Logistics variable reflects the extent to which the company optimises transport, prefers low-impact suppliers and packaging, and sets measurable targets to reduce emissions and waste (mean of DECARB1–DECARB3, Cronbach's alpha = 0.825).	Mean: 3.58 St.dev.: 1.32 Min: 1 Max: 6.33
INOV	Innovation Orientation variable reflects the extent to which the company introduces new products or services, experiments with delivery models, and invests in rapid testing (mean of INOV1–INOV3, Cronbach's alpha = 0.866).	Mean: 4.07 St.dev.: 1.43 Min: 1 Max: 7

Code	Description	Summary descriptive statistics
RISK	Supply Risk Management Maturity variable reflects the extent to which the company secures alternative suppliers, holds safety stocks, and applies clear procedures for disruptions (mean of RISK1–RISK3, Cronbach's alpha = 0.810).	Mean: 4.45 St.dev.: 1.37 Min: 1 Max: 7
Control factors capturing the store's profile		
STORE_TYPE	What type of store do you operate?	1: Specialised (e.g., bicycles, sports clothing, or sports footwear) 65.5% 0: Generalist (mix of sporting goods) 34.5%
EMP_TOTAL	What is the total number of employees (including part-time)?	Mean: 6.14 St.dev.: 3.00 Min: 2 Max: 12
STORE_AGE	How many years has your store been in operation?	Mean: 10.5 St.dev.: 6.03 Min: 1 Max: 21
SALES_AREA	The sales area of your store (m²).	Mean: 128.4 St.dev.: 44.0 Min: 33 Max: 238

[$]*Std.dev. = standard deviation. Source: authors' calculations in STATA 18.*

Table no. 2. Constituent items of the composite variables

Variable	Description	Descriptive Statistics
All items are measured on the following scale: 1 = Not at all true for our store … 7 = Completely true for our store.		
DIGI 1	Does your company use digital solutions for inventory management (e.g., barcodes/RFID systems, automated updates)?	Mean: 3.92 St.dev: 1.44 Min: 1 Max: 7
DIGI 2	Does your company have digital integration with suppliers (e.g., automatic orders/confirmations, EDI)?	Mean: 3.99 St.dev: 1.43 Min: 1 Max: 7
DIGI 3	Does your company monitor operational indicators in real time (e.g., stockouts, replenishment time)?	Mean: 3.85 St.dev: 1.92 Min: 1 Max: 7
DECARB 1	Does your company optimise routes/transportation to reduce fuel consumption and emissions?	Mean: 3.62 St.dev: 1.20 Min: 1 Max: 7
DECARB 2	Does your company prefer suppliers/packaging with reduced environmental impact (e.g., recycled/recyclable materials)	Mean: 3.70 St.dev: 1.20 Min: 1 Max: 6

Variable	Description	Descriptive Statistics
DECARB 3	Does your company have measurable targets for reducing emissions/waste in operations?	Mean: 3.43 St.dev: 1.51 Min: 1 Max: 7
INOV 1	Does your company frequently introduce new products/services (e.g., bike service, rental, fitting)?	Mean: 4.05 St.dev: 1.45 Min: 1 Max: 7
INOV 2	Does your company experiment with delivery/fulfilment models (e.g., click & collect, same-day delivery)?	Mean: 4.10 St.dev: 131 Min: 1 Max: 7
INOV 3	Does your company allocate resources for rapid testing of ideas and in-store pilots?	Mean: 4.07 St.dev: 1.99 Min: 1 Max: 7
RISK 1	Does your company have alternative suppliers for critical items (multi-sourcing)?	Mean: 4.52 St.dev: 1.47 Min: 1 Max: 7
RISK 2	Does your company maintain safety stocks for products with volatile demand?	Mean: 4.40 St.dev: 1.40 Min: 1 Max: 7
RISK 3	Does your company have clear procedures for disruptions (e.g., continuity plans, escalation criteria)?	Mean: 4.44 St.dev: 1.91 Min: 1 Max: 7

[$]*Std.dev. = standard deviation. Source: authors' calculations in STATA 18.*

Statistical methodology - Ordered Logit Model.

The empirical analysis applies an Ordered Logit Model (OLM), appropriate for ordinal dependent variables. The outcomes considered are *SALES_LEVEL*, *SUPPLY_STAB*, and *COMP_POS*, each defined on a 1-5 Likert scale. The ordered nature of these responses justifies the choice of OLM. The model assumes the existence of an unobservable continuous latent variable Y_i^*, linked to the observed ordinal responses through threshold parameters. The structural equation is:

$$Y_i^* = \alpha + \sum_{j=1}^{k} \beta_j X_{ij} + \varepsilon_i, \quad \varepsilon_i \sim \text{Logistic}(0,1) \tag{1}$$

The observed outcome is obtained as:

$$Y_i = m \quad \text{if} \quad \mu_{m-1} < Y_i^* \leq \mu_m, \qquad m = 1, \ldots, M \tag{2}$$

with μ_0=-∞ and μ_M=-∞. The probability of being in category *m* conditional on *X* is:

$$P(Y_i = m \mid X_i) = \Lambda(\mu_m - \beta X_i) - \Lambda(\mu_{m-1} - \beta X_i) \tag{3}$$

where $\Lambda(z) = \frac{1}{1+e^{-z}}$ is the logistic cumulative distribution function.

3. Results and discussion

3.1. Findings from the descriptive statistics

The descriptive statistics from Table no. 1 and 2 reveal several interesting patterns regarding the dependent and explanatory variables. In terms of *SALES_LEVEL*, the largest proportion of stores (37.1%) rate their sales performance as "Medium," while 24.7% consider it "High" and only 10.0% report "Very High," suggesting that most businesses position themselves in the mid-range, with only a minority achieving exceptional outcomes. Supply conditions, measured by *SUPPLY_STAB*, appear relatively solid, since 40.6% of respondents describe their supply as "Stable" and a further 20.0% as "Very Stable," which indicates a generally favourable perception of supply reliability. On the other hand, competitive positioning (*COMP_POS*) seems less advantageous, with 32.8% rating themselves "Below Competitors" and just 3.7% claiming to be "Much Above Competitors," pointing to challenges in achieving a distinct edge in the local market. Among the explanatory constructs, *DIGI* shows a mean of 3.92 (SD = 1.31), reflecting a moderate degree of logistics digitalisation, while its Cronbach's alpha of 0.738 demonstrates acceptable internal reliability. The *DECARB* variable has a mean of 3.58 (SD = 1.32), indicating that sustainability-related practices are present, but still at a developing stage, with reliability strongly supported by an alpha of 0.825. Innovation orientation (*INOV*) emerges as comparatively more advanced, with the highest average value of 4.07 (SD = 1.43), suggesting that many stores experiment with new services and delivery models; its Cronbach's alpha of 0.866 confirms excellent measurement consistency. Finally, the *RISK* dimension records a mean of 4.45 (SD = 1.37), showing that stores devote significant attention to risk management through multi-sourcing, safety stocks, and contingency planning, and this construct is also highly reliable (Cronbach's alpha = 0.810). Overall, the descriptive results highlight a sample of stores that are reasonably stable in supply management, moderately advanced in digital and green practices, and particularly strong in innovation and risk management, with all multi-item constructs exhibiting satisfactory to excellent internal consistency.

The distributions presented in Figures 1-3 illustrate distinct patterns across the groups of variables. The three dependent variables exhibit clearly different shapes: *SALES_LEVEL* is skewed toward middle categories, *SUPPLY_STAB* shows a concentration in higher values reflecting generally stable supply chains, while *COMP_POS* is more dispersed with a notable share reporting below-average competitiveness. These differences make economic sense, since sales tend to cluster around average performance, supply chains are generally robust in stable retail markets, and competitiveness is inherently uneven across stores. Such ordered but non-continuous patterns strongly support the choice of the Ordered Logit Model, which is specifically designed for categorical outcomes with ranked levels. By contrast, the main explanatory indices (*DIGI*, *DECARB*, *INOV*, *RISK*) display distributions close to normality, which is expected because they are composite constructs built as sums of items, and the Central Limit Theorem implies approximate normality in such cases. This contributes to the robustness of the measures and facilitates their use as predictors. Finally, the control variables (*STORE_TYPE*, *EMP_TOTAL*, *STORE_AGE*, *SALES_AREA*) reveal sensible distributions, with categorical balance in store type and reasonable spread in size and age, further indicating that the dataset is suitable for multivariate modelling.

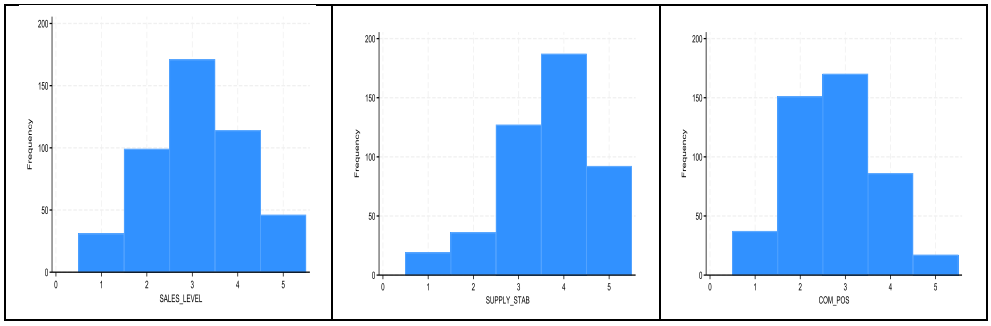

Figure no. 1. Distributions of dependent variables values

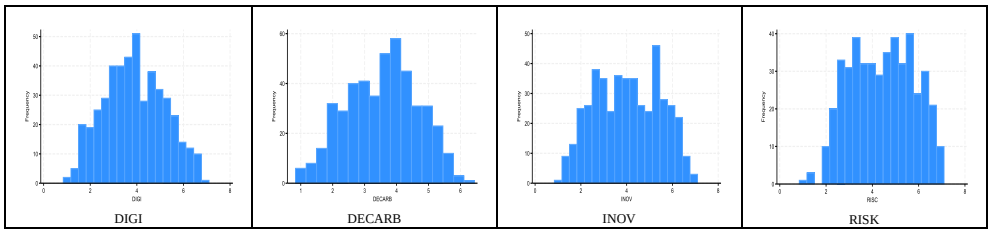

Figure no. 2. Distributions of values for the key explanatory variables

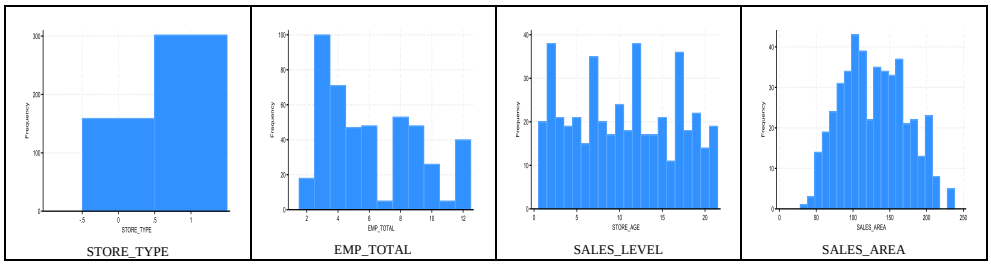

Figure no. 3. Distributions of control factor values

3.2. Empirical results of the regression analysis

The results of the three ordered logit regressions are presented in Table no. 3. In the first regression, DIGI has the most consistent and powerful effect, showing a positive coefficient of 0.4527 on SALES_LEVEL, significant at the 1% level. INOV also contributes positively to SALES_LEVEL, with significance at 5%, confirming its role as a relevant predictor. RISK enters the same model with a smaller positive coefficient of 0.1111, but only significant at 10%, which raises doubts about the robustness of the relationship. In the second regression, the strongest factor is RISK, with a positive coefficient of 0.1851 on SUPPLY_STAB, significant at the 1% threshold, confirming its central role in supply reliability. DIGI is also positive in this model, with a significance of 5%, supporting the idea that digital practices improve supply stability. DECARB has a positive coefficient of 0.1275 for SUPPLY_STAB, but this is significant only at the 10% level, meaning that the result has limited representativeness. In the third regression, INOV stands out with a large positive coefficient of 0.3435 on COMP_POS, highly significant at 1%, making it the strongest effect in this equation. DIGI again proves relevant, with a positive coefficient of 0.1396, significant at 5%,

reinforcing its stable contribution across models. DECARB also enters positively for COMP_POS, with a coefficient of 0.1661, significant at 5%, suggesting that the green orientation plays a role in competitiveness. RISK shows another positive effect in the third regression, significant at 5%, though its coefficient of 0.1632 is smaller than that of innovation. Among the control variables, SALES_AREA is positive and significant at 5% in explaining SALES_LEVEL, with a coefficient of 0.0055, suggesting that larger stores perform better in sales. At the weaker 10% level, STORE_TYPE shows a negative effect on SUPPLY_STAB but a positive effect on COMP_POS, results that suggest possible patterns but without strong statistical support. EMP_TOTAL appears with mixed signs, positive for SALES_LEVEL and negative for COMP_POS, both only at the 10% threshold, making these findings suggestive but not definitive. STORE_AGE displays a weak positive coefficient for SUPPLY_STAB, also at 10%, while in the other regressions it shows no significant impact. Some results remain clearly non-significant, such as DECARB in the SALES_LEVEL model, where the coefficient is negative and close to zero, although theoretically a positive link could have been expected. Similarly, INOV has no effect on SUPPLY_STAB, with a coefficient close to zero, again diverging from theoretical expectations. STORE_TYPE in the first regression and STORE_AGE in the third regression are also statistically insignificant, offering no empirical confirmation of potential causal relationships.

The multicollinearity diagnostics show that the Condition Index values ranged between 5.6 and 12.8, all comfortably below the critical threshold of 30, confirming that the explanatory constructs are sufficiently independent. The proportional odds assumption was validated, as the Likelihood Ratio test comparing the restricted and generalised logit models produced a χ^2 value of 14.3 with 12 degrees of freedom and a corresponding $p = 0.27$, indicating no violation of the assumption. These methodological checks suggest that the inclusion of digitalisation, decarbonisation, innovation, and risk management variables, alongside the controls for store type, number of employees, age, and sales area, does not generate multicollinearity or specification bias.

Table no. 3. Sustainability reporting and its determinants: ordered logit model estimates on organisational readiness (coefficients and *z*-stat)

	OLM1 Dep. var: SALES_LEVEL		**OLM2 Dep. var: SUPPLY_STAB**		**OLM3 Dep. var: COM_POS**	
	Coef.	z	Coef.	z	Coef.	z
DIGI	0.4527	***6.51	0.1424	**2.12	0.1396	**2.08
DECARB	-0.0150	-0.19	0.1275	*1.66	0.1661	**2.13
INOV	0.1245	**2.06	0.0011	0.02	0.3435	***5.51
RISC	0.1111	*1.74	0.1851	***2.88	0.1632	**2.50
STORE_TYPE	-0.0386	-0.21	-0.3126	*-1.72	0.3180	*1.73
EMP_TOTAL	0.0632	*1.78	-0.0094	-0.26	-0.0607	*-1.71
STORE_AGE	-0.0281	*-1.96	0.0274	*1.91	-0.0092	-0.64
SALES_AREA	0.0055	**2.32	-0.0009	-0.39	0.0044	*1.85

****, **, * significant at 1%, 5%, 10%*
Source: own calculations in STATA 18

3.3. Interpretation of the main findings

Our findings align with previous studies that emphasise digitalisation and innovation as central drivers of retail performance. For instance, Ishfaq et al. (2021) and Zhao et al. (2023) highlight the transformative role of digital tools in improving agility and resilience, while our results show that digitalisation is a consistent positive determinant of both sales and supply stability. Similarly, innovation is strongly linked to competitive positioning, echoing Pantano et al. (2017) and Albors-Garrigos (2020), who argue that retail competitiveness depends on experimentation and customer-oriented innovation. However, unlike previous studies that underline the integrative benefits of innovation for supply chain robustness (Lambert & Enz, 2017; Li et al., 2023), our evidence suggests that innovation in small sporting goods stores does not translate into greater supply stability.

Risk management maturity emerges as another significant predictor, consistent with the arguments of Gurtu and Johny (2021) and Lochan et al. (2021), who stress redundancy and safety stocks as effective mechanisms for supply continuity. This indicates that small retailers rely on conventional tools to ensure stability, even if they fall short of more advanced, technology-enabled practices discussed by Baryannis et al. (2018). In contrast, decarbonisation shows mixed effects: while green practices support competitive positioning, confirming arguments by Qian et al. (2019) and Fuchs and Hovemann (2022), their influence on supply stability is weaker and only marginally significant, suggesting that sustainability measures are not yet fully embedded in operational resilience.

Control factors also provide meaningful insights. Store size, proxied by sales area, is positively associated with sales performance, which aligns with the idea that larger facilities benefit from economies of scale and better assortments. Store type reveals ambiguous results, showing a negative link to supply stability but a positive one to competitive position, indicating that specialisation may generate strategic differentiation but also greater vulnerability in sourcing. Employment size and store age exhibit limited or inconsistent effects, implying that organisational resources and experience do not systematically translate into better performance outcomes.

Taken together, the results provide strong support for H1, H2, and H3, confirming that digitalisation, risk management, and innovation orientation play decisive roles in shaping sales, supply stability, and competitiveness. H4, regarding the role of decarbonisation, is only partially supported, with clearer effects on competitiveness than on supply stability. H5, which anticipated a positive role of innovation in stabilising supply chains, is not validated, as no significant effect was observed. Overall, the findings highlight that while digital and risk practices drive stability and performance, innovation and green strategies primarily shape competitive differentiation, though their operational benefits remain underdeveloped in small-scale sporting goods retail.

Conclusions

This study examined how digitalisation, decarbonisation, innovation, and supply risk management practices shape sales performance, supply stability, and competitive positioning in independent sporting goods retail. The empirical results show that digitalisation and innovation are the most consistent predictors of performance outcomes, while risk management plays a central role in stabilising supply chains. Green logistics practices contribute to competitiveness, but remain underdeveloped with respect to operational

resilience, indicating a gap between environmental ambitions and day-to-day business constraints.

The paper contributes to the academic debate by extending supply chain and retail research into the underexplored context of small, independent sporting goods stores. Unlike studies focused on multinational retailers, our findings show that incremental practices—modest digital tools or redundancy-based risk management—are central to performance under resource constraints. This suggests that theories of resilience and competitiveness must account for scalability and the limited absorptive capacity of small firms.

From a theoretical standpoint, the results refine existing frameworks by showing that the interactions among digitalisation, innovation, sustainability, and risk management differ from patterns observed in large, integrated retail chains. In particular, the study demonstrates that these relationships are partly sector-specific, reflecting characteristics of the sporting goods market such as seasonality, product specialisation, and dependence on niche suppliers. Practically, the study highlights that even incremental investments in digital tools and innovation can yield meaningful performance gains, while structured but simple risk management routines improve supply stability in small stores.

Managers should therefore prioritise targeted digital upgrades, systematic experimentation with delivery and service innovations, and the adoption of basic but consistent risk mitigation practices. Based on our findings, we recommend that small retailers focus on strengthening supplier relationships, integrating low-cost monitoring tools, and progressively embedding green practices that have immediate cost or image benefits. These recommendations are directly grounded in the observed empirical patterns and tailored to the structural realities of independent sporting goods retailers.

The research is not without limitations. The cross-sectional design restricts causal interpretations, and the study relies on self-reported assessments that may contain perceptual bias. Additionally, the Romanian context may limit the generalisability of certain findings to countries with different institutional or market environments. However, many of the mechanisms identified—particularly those related to supply stability and innovation—appear tied to the structural characteristics of the sporting goods sector, indicating that some results may be domain-specific rather than universally generalisable.

Future research could adopt longitudinal designs to capture dynamic changes in digitalisation, sustainability, and innovation practices. Cross-country comparisons and multi-sector studies would further clarify which findings are specific to independent sporting goods retail and which reflect broader patterns across small-scale retail environments. Investigating sub-segments within the sporting goods industry may also reveal whether the magnitude of these effects varies across product categories or business models.

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SPORT, CULTURE, AND PURCHASING POWER: INFLUENCES ON FOOD MARKETS AND CONSUMPTION

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Abstract
This study aimed to investigate the influence of economic, cultural, and lifestyle factors on food consumption patterns in 31 European and associated countries between 2010 and 2020. A panel econometric model with random effects was used to analyse data from international sources, including GDP adjusted for purchasing power parity, cultural indices, and food consumption statistics. The findings revealed that increased sports participation and purchasing power significantly increased vegetable, fruit, and fish consumption, while cultural values such as individualism and long-term orientation shaped dietary preferences. Unlike previous research that focused on individual-level factors, this study integrated macroeconomic determinants to provide a comprehensive analysis of national food consumption trends. Furthermore, critical shifts in the food market were identified, including the increasing demand for healthy and sustainable products, highlighting the challenges faced by food chain actors in adapting to these changes. The results provide a valuable framework for policy makers and business strategies, highlighting the need for resilience, innovation, and market adaptation to align with evolving consumer preferences.

Keywords: food consumption structure, sports participation, purchasing power, cultural values, driving market shifts.

JEL Classification: Q18, C23, Z20.

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Introduction

Studying changes in the food market by examining consumer demand for food products and its economic and behavioural drivers is important to understand how the food industry is changing. Consumer preferences are evolving, with more people choosing healthier, sustainable, and locally sourced foods, which directly impacts the products offered on the market. Technological innovations are also reshaping the food industry, enabling new efficient ways to produce, process, and distribute food, while creating opportunities for different business models throughout the supply chain. Sustainability is a key concern as the food industry is under pressure to reduce environmental impacts while meeting consumer expectations and remaining profitable. Businesses must also develop resilience and adapt to these market changes to remain competitive. Effective marketing and communication play an important role in connecting food producers, processors, and retailers with current consumer trends. By aligning all parts of the food chain with these trends, companies can better respond to market demands and improve their long-term success.

The structure of food consumption (how much people eat vegetables, fruits, fish or meat) is heavily influenced by health awareness and sports activity. People who are health conscious often prioritise diets high in fruits, vegetables, and fish due to the known health benefits of these foods, such as vitamins, antioxidants, and lean proteins. Regular sports participation further shapes these choices, as active people tend to choose leaner, protein-rich options that support physical performance, such as poultry and fish, over red meat. In many European countries, the growing popularity of sports and fitness has led to an increased demand for 'health foods', including organic produce and high-protein items, creating a trend towards balanced and nutritious diets. Additionally, purchasing power allows health conscious consumers to purchase premium food items such as fresh fish or organic vegetables, which are often more costly. This trend is strong in Northern Europe, where health and fitness are culturally emphasised, leading to diets rich in fish and plant-based foods. In southern Europe, although traditional diets are high in vegetables and fish, there is also growing awareness of healthy eating and fitness. Cultural values that promote well-being and active lifestyles can strongly impact dietary choices, as seen in countries such as Sweden and Denmark. In general, sports and health concerns are key drivers of food consumption patterns throughout Europe, contributing to a shift toward balanced diets that align with active and health-focused lifestyles.

The academic literature extensively explores food consumption patterns, but most studies focus on individual-level factors, such as why a person chooses one type of food over another. However, understanding the structure of food consumption at the national level is equally important, as it reveals broader trends that shape market demands. Our study addresses this gap by examining how national determinants, such as economic factors, cultural values, health trends, and participation in sports, collectively influence food consumption patterns. The *originality of our research* lies in its comprehensive macro-level perspective, which integrates these diverse determinants into a unified analytical framework. Unlike existing studies, our approach highlights how societal preferences and behaviours drive changes in food markets, providing essential insights for policymakers, companies, and public health advocates. By focussing on European countries, we emphasise the geographical and cultural diversity of food preferences across the continent. For example, physically active and health conscious populations are driving the increased demand for lean proteins and fresh produce, prompting producers and retailers to adapt accordingly. This has significant implications for

food market shifts, as businesses in the food chain must respond to regional trends in consumer demand to remain competitive. The findings can guide companies in tailoring their offerings to meet changing dietary patterns, leading to more effective strategies and product development. Our study provides insights into how evolving consumer needs impact the food market, helping stakeholders better anticipate and respond to changes in market dynamics throughout Europe.

The article begins with a *review of the literature* that examines academic research on factors likely to influence the structure of food consumption. The next section, *Research Methodology*, details the data sources from EU and associated countries, defines the variables used in the empirical study, and describes the statistical approach. This methodology includes panel econometrics, relevant tests, as well as the role of descriptive statistics and graphical visualisations. In the *Results and Discussion* section, the article highlights trends emerging from descriptive statistics and presents the findings from econometric estimations, followed by an analysis of these results. The article closes with the *Conclusions* section, which includes a summary of findings, study limitations, directions for future research, and policy implications.

1. Review of the literature

The academic literature on food consumption is extensive. However, it focusses mainly on individual behaviour. Our approach is different, targeting the macro-level. We examine national determinants of food consumption. The literature review is divided into four parts. First, we analyse how sports participation influences the consumption structure. Second, we explore the impact of purchasing power on consumption preferences. Third, we investigate the link between cultural values and specific product groups. Finally, we assess how product demand affects the functioning of specific markets.

Sports and Food Consumption Preferences. Sports participation significantly influences dietary choices, as people engaged in physical activity tend to prioritise nutrient-dense foods for performance and recovery. Meyer and Reguant-Closa (2017) emphasise the role of protein-rich diets, particularly meat and dairy, and incorporate sustainability as a growing concern in sports nutrition. This aligns with Dagevos and Van Ophem (2013), who introduce the concept of Food Consumption Value (FCV), explaining that food choices in sports reflect broader values such as health and well-being. However, Çebi et al. (2020) take a different approach, focussing on meal timing and frequency, especially breakfast habits, as critical factors in maintaining diet quality among students from sports faculty. While both perspectives acknowledge structured eating habits, Meyer and Reguant-Closa (2017) integrate ethical concerns, whereas Çebi et al. (2020) emphasise the physiological benefits of planned eating patterns. Beyond structured meals, Cui et al. (2022) highlight the rapid expansion of the sports food industry, driven by the growing demand for energy-dense bars, protein supplements, and specialised sports products. This commercialisation of sports nutrition contrasts with Fieldhouse (2013), who examines the cultural and social norms that shape food choices in active individuals, demonstrating how societal expectations influence dietary behaviour. Although Cui et al. (2022) analyse market-driven shifts, Fieldhouse (2013) focusses on how cultural narratives surrounding nutrition affect athletes' preferences. Furthermore, sports participation often correlates with a greater focus on healthy foods such as fruits and vegetables, aligning with the broader goal of optimising performance. This trend

is supported by Dagevos and Van Ophem (2013), who suggest that FCV helps explain why athletes and active people may prioritise food choices based on long-term health benefits. However, this contrasts with Çebi et al. (2020), who argue that structured eating routines and meal frequency are more immediate determinants of dietary quality than ethical or health-conscious motivations. Together, these studies demonstrate how sports-related food choices are shaped by commercial influences (Cui et al., 2022), structured dietary habits (Çebi et al., 2020), cultural expectations (Fieldhouse, 2013), and personal values (Dagevos and Van Ophem, 2013). Although some emphasise the impact of the market and industry on sports nutrition, others highlight the role of meal structure, cultural norms, or ethical considerations in shaping dietary behaviour. This interplay of factors underscores the complexity of food preferences in sports and fitness contexts.

Purchasing Power and Food Preferences. Purchasing power is a critical determinant of food preferences, influencing consumers' access to a variety of foods. Higher incomes generally allow consumers to afford more nutritious and diverse foods, such as fruits, vegetables, and lean proteins (European Commission, 2024). Fallo, Nuhriwangsa and Hanim (2019) examine how purchasing power affects the consumption of fruits and vegetables among elementary students, finding a significant correlation between income and diet quality. Ayaviri-Nina et al. (2022) study rural families in Ecuador, showing that higher family income is related to greater food security, whereas low purchasing power limits dietary diversity. Similarly, Bandara et al. (2021) explore changes in food consumption patterns in Sri Lanka, highlighting how income growth and urbanisation drive the demand for diverse food products beyond traditional staples. Blisard et al. (2002) provides further evidence by projecting US food spending growth based on income trends, suggesting that increased purchasing power will expand demand for diverse food options. Zhang, Grunert and Zhou (2020) also discuss consumer interest in local foods, noting that purchasing power enables the support of locavorism in developed markets. As purchasing power increases globally, it redefines consumer demand for high quality, premium, and locally sourced food products, prompting changes in the food market to meet these preferences.

Cultural Values and Food Preferences. Cultural values are fundamental determinants of food choices, shaping dietary habits through long-standing social norms and traditions. Djekic et al. (2021) explore the relationship between Hofstede's cultural dimensions and food choice, showing that individualistic and uncertainty-averse cultures tend to favour health-conscious diets. This aligns with Nemeth et al. (2019), who examine international students in Hungary and find that cultural backgrounds significantly influence dietary preferences, often reinforcing the tendency to maintain traditional eating patterns even when living abroad. Similarly, De Mooij and Hofstede (2011) demonstrate that cultural norms impact consumer behaviour, influencing both food selection and broader consumption habits in different societies. At a global level, Kearney (2010) highlights how cultural factors shape the nutrition transition in developing countries, with dietary changes occurring at different rates depending on societal norms and exposure to globalisation. This cultural influence extends to the ethical and emotional dimensions of food consumption, as described by Dagevos and Van Ophem (2013), who introduce the concept of Food Consumption Value (FCV). They argue that cultural values shape food choices by integrating health, sustainability, and personal beliefs into purchasing decisions, which contrasts with purely economic drivers. In this context, Feldmann and Hamm (2015) offer a complementary perspective by analysing how cultural values and local food preferences interact. Their study reveals that while local food is often associated with freshness and quality, consumer demand varies significantly based on

cultural attitudes toward food origin, authenticity, and sustainability. This connects with Sun, Horn and Merritt (2009), who identify cultural dimensions such as masculinity and self-consciousness as factors that encourage healthier eating habits, demonstrating how identity influences food choices. Taken together, these studies illustrate that cultural values influence food preferences through a combination of tradition, identity, and ethical considerations. Although Feldmann and Hamm (2015) emphasise the cultural motivations behind local food consumption, Djekic et al. (2021) and Nemeth et al. (2019) focus on how cultural dimensions and migration affect food choices. This collective evidence underscores the profound role of cultural norms in the shaping of national and regional food markets, demonstrating how both individual preferences and societal expectations contribute to dietary behaviour.

Consumer preferences and market trends. Consumer preferences are evolving, with a growing focus on health, sustainability, and local food supply, all of which are key drivers of market trends. Kearney (2010) highlights a global shift toward more diversified diets, driven by urbanisation and rising incomes, which broadens consumer demand for varied and nutritious food options. This aligns with Hartman-Petrycka et al. (2024), who find that younger consumers increasingly prioritise balanced diets rich in vegetables and fish due to health and environmental concerns. Similarly, Larson (2004) explores market segmentation based on food consumption patterns, helping businesses tailor products to align with regional dietary preferences. Beyond these economic and demographic influences, Dagevos and Van Ophem (2013) introduce the concept of Food Consumption Value (FCV), arguing that emotional and ethical considerations play a significant role in shaping food choices. This perspective aligns with Meyer and Reguant-Closa (2017), who examine sustainability in sports nutrition, highlighting that athletes increasingly opt for foods that align with environmental concerns. Zhang, Grunert and Zhou (2020) further explore the growing preference for local food, particularly in environmentally conscious markets like Denmark, where "locavorism" reflects both ethical and health-driven motivations. In this context, Rana and Paul (2017) provide a broader framework to understand consumer behaviour, particularly in the organic food market. Their study highlights how health awareness, environmental awareness, and trust in certification systems contribute to shifting food preferences, particularly as consumers seek products perceived as safer and more sustainable. This is particularly relevant to Ho et al. (2022), who examine how cultural backgrounds influence attention to food labels, shaping consumer perceptions of product authenticity and quality. Together, these studies illustrate how consumer preferences are shaped by a combination of economic, ethical, and health-related factors. Although Kearney (2010) and Hartman-Petrycka et al. (2024) focus on the role of income and generational trends, Rana and Paul (2017) provide insight into the psychological and environmental motivations behind food choices. These evolving preferences continue to shape food markets, requiring producers and retailers to adapt to the growing demand for healthier, sustainable, and ethically sourced products.

Macro approach and potential determinants. The specialised literature, focussing primarily on individual determinants of food consumption, highlights several factors. These factors will be examined at the macro level in our study of European countries. Increased participation in sports at the national level encourages healthier dietary choices, shifting the population's food consumption structure toward a higher intake of vegetables, fruits, and lean proteins such as chicken and fish. This shift often results in reduced consumption of red meats, such as pork and beef, as well as an increased preference for nutrient-dense options, such as seafood, aligning with the nutritional demands of an active lifestyle. The average

purchasing power in a country significantly influences the population's food consumption structure. A higher purchasing power typically increases the consumption of premium products such as beef, fish, and seafood, while a lower purchasing power shifts preferences toward more affordable options such as vegetables, fruits, and chicken. *Cultural indicators* such as Individualism (IDV), Long-Term Orientation (LTO), and Uncertainty Avoidance (UAI) significantly shape a country's food consumption patterns. Higher IDV may lead to diverse diet choices and a focus on convenience, favouring items such as chicken and seafood. Strong LTO encourages sustainable and health-conscious consumption, increasing the demand for vegetables, fruits, and fish. High UAI promotes traditional and familiar foods, such as pork and beef, over exotic or less common options. Other Hofstede dimensions, like Power Distance (PDI) and Masculinity (MAS), are theoretically less relevant, as they primarily influence hierarchical relationships or competitiveness rather than direct food choices.

2. Research methodology

A significant gap in existing research lies in the lack of a comprehensive methodological framework that integrates the economic, cultural, and behavioural determinants of food consumption at the macrolevel. Although previous studies have explored these factors individually, few have used panel econometric techniques to systematically capture their combined effects over time and in multiple countries. This study addresses this limitation by applying robust statistical methods and multisource data integration to provide a more nuanced understanding of food market dynamics and consumer behaviour.

Statistical methodology. The core methodology for validating the study's hypotheses is panel-data econometrics. As an auxiliary element, we use descriptive statistics and graphical representations (maps) to visualise the spatial dynamics of the phenomenon. Maps can also highlight potential behavioural mimicry among geographical neighbours. The empirical analysis is conducted on a sample of 31 European countries, including EU members and associated states, covering the period 2010-2020, as this is the only timeframe for which complete data are available for all study variables. Given the relative stability and low volatility of the variables used in our study (such as Hofstede's cultural factors), no significant structural changes were observed in consumption patterns or explanatory variables due to the COVID-19 pandemic or other external factors. The descriptive statistics and geographic visualisation of the data are considered preliminary analyses that are used to identify potential trends. The confirmatory methodology is based on panel econometrics applied to data from the countries in the sample. Prior to estimation, we conducted standard pre-estimation tests. These steps ensure the robustness of the econometric analysis.

The Breusch-Pagan Lagrange Multiplier (LM) test evaluates whether a random-effects model is justified over an OLS model by testing for significant variation across cross-sectional units. The hypotheses are as follows: *H0*: no random effects, and *H1*: random effects present.

$$LM = \frac{T}{2(N-1)} \sum_{i=1}^{N} \left(\frac{\sum_{t=1}^{T} (y_{it} - \bar{y}_i)^2}{\sum_{i=1}^{N} \sum_{t=1}^{T} (y_{it} - \bar{y})^2 / (N-1)} - 1 \right)^2 \quad (1)$$

- *T* represents the number of time periods (3 years: 2010, 2015, 2020),

- N is the number of units (31 countries),
- y_{it} is the value of the dependent variable for country i in period t,
- $\bar{y}_i$ is the country-level mean of the dependent variable across all time periods,
- y is the overall mean of the dependent variable across all countries and time periods.

If the p-value of the LM test is <0.05, we reject H0 and conclude that random effects are present, making the random effects model appropriate.

The Hausman test helps to choose between fixed- and random-effects models by checking if individual effects are correlated with explanatory variables, with hypotheses: *H0*: random effects model is appropriate (no correlation) and *H1*: fixed effects model is appropriate (with correlation).

$$H = (\beta_{FE} - \beta_{RE})' \left(\mathrm{Var}(\beta_{FE}) - \mathrm{Var}(\beta_{RE})\right)^{-1} (\beta_{FE} - \beta_{RE}) \quad (2)$$

- β_{FE} represents the econometric estimates for the fixed effects model,
- β_{RE} represents the econometric estimates for the random effects model,
- Var(β_{FE}) and Var(β_{RE}) are the variance matrices for the estimates of the two models.

To use random effects, the Hausman test statistic H should not be statistically significant; that is, the p-value should be greater than the chosen significance level (α=0.05). If the p-value > 0.05, we do not reject the null hypothesis, indicating that the random effects model is appropriate.

In our estimations, the Breusch-Pagan LM and Hausman tests indicate the suitability of using random-effects models. The random-effects model assumes that individual-specific effects are uncorrelated with the explanatory variables, allowing variation across entities (such as countries) to be treated as random and included in the error term, making it more efficient for estimating coefficients when this assumption holds. Unlike the fixed effects model, which controls for all time-invariant characteristics, and the pooled OLS model, which assumes no individual-specific variation, random effects strike a balance by partially accounting for unobserved heterogeneity while retaining efficiency. Our estimations are based on the following regressions:

$$FREQVEGCONS_{it} = \alpha + \beta_1 SPORT_{it} + \beta_2 GDP\_PPP_{it} + \beta_3 IDV_{it} + \beta_4 LTO_{it} + \beta_5 UAI_{it} + u_i + \epsilon_{it} \quad (3)$$

$$FREQFRUCONS_{it} = \alpha + \beta_1 SPORT_{it} + \beta_2 GDP\_PPP_{it} + \beta_3 IDV_{it} + \beta_4 LTO_{it} + \beta_5 UAI_{it} + u_i + \epsilon_{it} \quad (4)$$

$$POULTRY\_TMC_{it} = \alpha + \beta_1 SPORT_{it} + \beta_2 GDP\_PPP_{it} + \beta_3 IDV_{it} + \beta_4 LTO_{it} + \beta_5 UAI_{it} + u_i + \epsilon_{it} \quad (5)$$

$$PORK\_TMC_{it} = \alpha + \beta_1 SPORT_{it} + \beta_2 GDP\_PPP_{it} + \beta_3 IDV_{it} + \beta_4 LTO_{it} + \beta_5 UAI_{it} + u_i + \epsilon_{it} \quad (6)$$

$$BEEF\_TMC_{it} = \alpha + \beta_1 SPORT_{it} + \beta_2 GDP\_PPP_{it} + \beta_3 IDV_{it} + \beta_4 LTO_{it} + \beta_5 UAI_{it} + u_i + \epsilon_{it} \quad (7)$$

$$FISH\_TMC_{it} = \alpha + \beta_1 SPORT_{it} + \beta_2 GDP\_PPP_{it} + \beta_3 IDV_{it} + \beta_4 LTO_{it} + \beta_5 UAI_{it} + u_i + \epsilon_{it} \quad (8)$$

- i indexes the observations (31 countries)
- t indexes the time (3 years, 2010, 2015, 2020).

Robustness check. To ensure the reliability of our estimates, we assessed potential multicollinearity and omitted variable bias (OVB). Given the distinct nature of our explanatory variables: economic (GDP_PPP), cultural (Hofstede dimensions), and lifestyle factors (sport participation), collinearity is unlikely. Empirical verification confirms this, with the highest Pearson correlation coefficient observed at 0.27 (between GDP_PPP and sports participation), far below the conventional threshold of 0.7. Regarding OVB, our model incorporates all key determinants identified in the literature that influence food consumption, including economic capacity, cultural orientation, and lifestyle choices. Inclusion of Hofstede dimensions captures deep-seated cultural effects, while GDP_PPP and sports participation control for economic and behavioural influences, reducing the likelihood of unobserved confounders. Additionally, the random effects panel model, validated by the Breusch-Pagan and Hausman tests, accounts for time-invariant heterogeneity between countries. These robustness checks confirm that neither multicollinearity nor omitted variables significantly distort our findings, ensuring the validity of our results.

Definition of variables. Table 1 presents all the variables used in the regressions, explanations of their definitions, and some descriptive statistics.

Table no. 1. Variables used and descriptive statistics

Variable code	Explanations regarding the variables	Mean	Std. Dev.[$]	Min	Max
Dependent variables					
FREQVEGCONS	Frequency of vegetable consumption. Percentage of the adult population who consumes vegetables at least 4 times a week.	70.7	3.72	64	80
FREQFRUCONS	Frequency of fruit consumption. Percentage of the adult population who consumes fruits at least 4 times a week.	49.9	20.6	11	80
POULTRY_TMC	Proportion of poultry in total meat consumption.	22.6	5.50	11.5	36.6
PORK_TMC	Proportion of pork in total meat consumption.	38.4	7.43	26.5	56.8
BEEF_TMC	Proportion of beef in total meat consumption.	17.3	4.97	9.1	31.0
FISH_TMC	Proportion of fish and seafood in total meat consumption.	21.6	6.59	8	35.6
Explanatory variables					
SPORT	The percentage of the population who participates in regular sports, at least once a week.	47.4	18.1	6.3	84.4
GDP_PPP	GDP adjusted for purchasing power parity, divided by the population (the average economic output per person in terms of local purchasing power). Log-transformed values are used in the regressions.	37764	15001	12582	85819

Variable code	Explanations regarding the variables	Mean	Std. Dev.$	Min	Max
IDV	Individualism vs. Collectivism. This indicator measures the degree to which individuals in a society are integrated into groups, with high IDV indicating a preference for individual autonomy and low IDV reflecting a focus on group cohesion.	54.4	18.2	20	80
LTO	Long-Term Orientation vs. Short-Term Orientation. This dimension assesses a culture's focus on future rewards, with high LTO favouring long-term planning, perseverance, and thrift, while low LTO emphasises respect for tradition and fulfilling social obligations.	51.9	15.2	19	83
UAI	Uncertainty Avoidance Index. The UAI measures the degree to which a society tolerates ambiguity and uncertainty, with a high UAI indicating a preference for rules and structure, and a low UAI showing greater openness to change and risk.	72.0	20.2	23	100

Note: Std.dev. = standard deviation.

Source: authors' calculations in STATA.

Data are sourced from highly credible international sources. We applied a few transformations to select variables to better align the estimates with the research objectives. The GDP_PPP variable is used in its logarithmic form because income is not linearly proportional to food consumption. Log-transforming GDP_PPP allows for a more accurate representation of its impact on consumption patterns. Additionally, GDP PPP per capita is preferred over nominal GDP per capita because it better reflects the real purchasing power and the cost-of-living differences between countries. The consumption of each meat product is expressed as a relative measure based on the average individual total meat consumption. Absolute consumption would have been overly dependent on each country's purchasing power. By focussing on consumption structure by meat type (POULTRY_TMC, PORK_TMC, BEEF_TMC, FISH_TMC), we capture more of the individual preferences. This approach allows us to better reflect the variation in dietary choices across countries.

$$POULTRY\_TMC = \left(\frac{POULTRY\_CONS}{POULTRY\_CONS + PORK\_CONS + BEEF\_CONS + FISH\_CONS} \right) \times 100 \quad (9)$$

Similarly, the relative consumption weights are defined for POULTRY, BEEF, and FISH.

National cultural values can also affect the structure of food consumption. Of the six cultural dimensions of Hofstede, only three (IDV, LTO, and UAI) have theoretical arguments that support causality in this context. Thus, these dimensions are included in our research as explanatory variables.

The data for this empirical study cover 31 countries, including EU members and associated states. Due to limited data availability for all countries in the world, we focused on this

sample with valid data from the European Statistical Institute. Some variables are sampled at intervals longer than a year, so our dataset includes data for the years 2010, 2015, and 2020. The data are sourced from credible international sources: World Bank – Indicators (2024), Hofstede Insights (2024), OECD (2024), European Commission (2024), and Our World In Data (2024).

3. Results and discussion

3.1. The results of descriptive statistics

The results of descriptive statistics (Table no. 1) indicate that 70.7% of the adult population in EU countries consumes vegetables at least four times a week, with low variability (SD = 3.72) between 64% and 80%. This consistency is likely due to widespread health campaigns and the general availability of vegetables throughout the EU. However, fruit consumption at the same frequency is significantly lower, averaging 49.9%, with much higher variability (SD = 20.6), ranging from 11% to 80%. This discrepancy may be influenced by regional dietary traditions and seasonal availability. In terms of meat consumption, poultry accounts for 22.6% of total meat consumption, varying between 11.5% and 36.6%, possibly due to its affordability and adaptability in local cuisines. Pork consumption is significantly higher, averaging 38.4% and ranging from 26.5% to 56.8%, reflecting strong cultural preferences and traditional recipes, particularly in central and eastern Europe. Beef constitutes 17.3% of total meat consumption, while fish and seafood make up 21.6%, with some countries consuming up to 35.6%, largely influenced by coastal proximity and long-standing fishing traditions. 47.4% of the population report regular sports participation, with a wide range (6.3% to 84.4%), which can be attributed to differences in national sports policies and lifestyle norms. Economic output per capita, adjusted for purchasing power, averages 37,764 but varies significantly (12,582 to 85,819), indicating economic disparities between EU countries. The individualism index averages 54.4, suggesting a balance between collective and autonomous societal values, while uncertainty avoidance is relatively high at 72, indicating a preference for structured environments, likely influenced by historical regulatory frameworks and institutional stability.

The findings on vegetable and fruit consumption align with Kearney (2010), who highlighted that urbanisation and public health campaigns play a crucial role in increasing vegetable intake, while fruit consumption remains more variable due to seasonal availability and regional dietary preferences. Additionally, the high pork consumption observed in central and eastern Europe supports De Mooij and Hofstede (2011), who emphasise the influence of cultural traditions on dietary habits, particularly in societies with strong culinary heritage and established food practices. These results underscore how public health initiatives and cultural norms shape dietary choices throughout the EU, reflecting the broader interaction between structural and behavioural factors in food consumption trends.

The results show clear regional disparities in sports participation in Europe (Figure no. 1). Denmark and Sweden report the highest participation rates, both at around 75%, reflecting a strong cultural emphasis on physical fitness in northern Europe. Germany and Luxembourg also have high engagement, with more than 60% of the population participating in sports weekly. In Western Europe, participation is moderate, with France at approximately 50% and Belgium at around 45%. In contrast, Southern and Eastern European countries exhibit lower participation rates; Italy reports around 35%, Greece approximately 30%, while Poland has

about 20%, and Romania ranks the lowest, with only 10% participation. These variations highlight a distinct north-south and west-east divide, where wealthier and more developed nations in the north and west tend to have significantly higher sports participation.

Discussion suggests that these findings align with Feldmann and Hamm (2015), who argue that lifestyle choices, shaped by economic conditions and cultural norms, significantly influence health-related behaviours, including sports participation. Higher participation in Northern and Western Europe may be linked to stronger public health initiatives and greater availability of sports facilities. Furthermore, the disparities between regions support the perspective of De Mooij and Hofstede (2011), who highlight those cultural dimensions, such as individualism and long-term orientation, impact engagement in physical activities. Countries with higher levels of individualism and a future-oriented mindset may be more likely to integrate sports into daily life, while regions with lower participation rates might prioritise other social and economic concerns. These results emphasise the role of both economic capacity and cultural values in shaping the trends of sports participation across Europe.

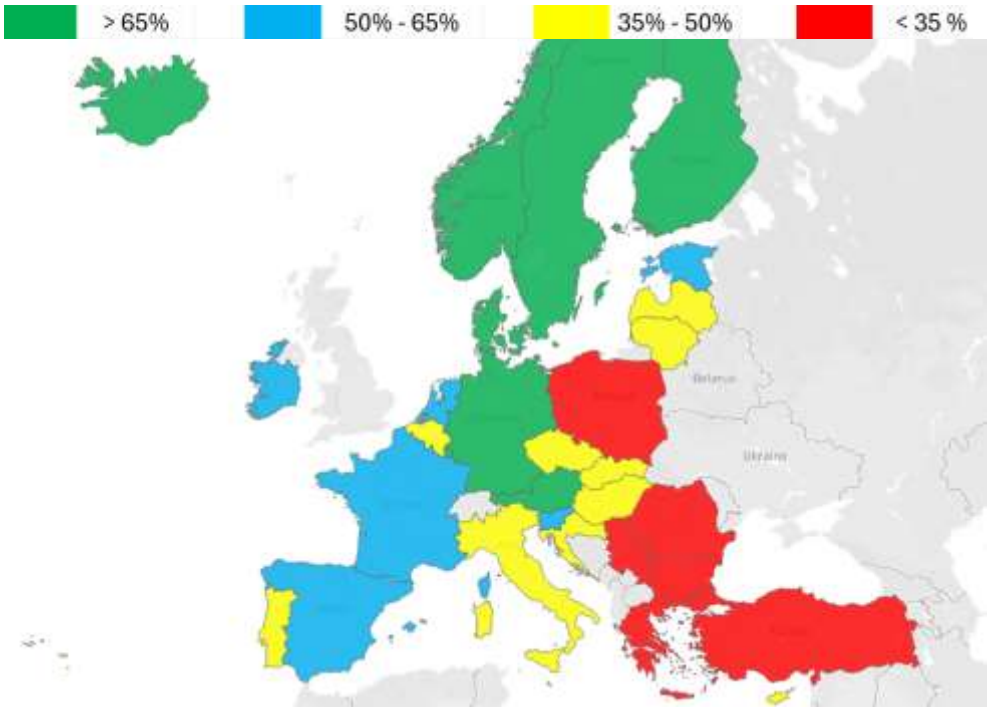

Figure no. 1. The percentage of the adult population that regularly practices sports
Source: authors' calculations in Tableau

The relative consumption of fish and seafood (Figure no. 2), measured as a percentage of total meat consumption, exhibits notable geographical disparities across Europe. Norway leads with the highest share at 42.6%, followed by Portugal (39.2%) and Sweden (32.3%), reflecting a strong preference for fish in the northern and coastal regions. This trend is likely to be shaped by both geographic proximity to the sea and long-standing cultural traditions

that emphasise seafood consumption. Similarly, Malta (31.5%), Finland (30.7%), and Spain (29.1%) report high rates of fish consumption, which align with Mediterranean and Scandinavian dietary patterns. In contrast, landlocked and eastern European countries tend to consume significantly less fish. For example, Serbia (9.1%), Slovakia (9.6%), and Poland (10.8%) have a low reliance on seafood, which may be explained by limited access to fresh seafood and traditional diets that prioritise other protein sources. Turkey has the lowest consumption rate of 5.8%, likely due to cultural preferences and economic constraints, as seafood can be relatively expensive. Countries such as Belgium (27.4%), France (29.2%), and Italy (29.3%) exhibit moderate levels of fish consumption, reflecting a balance between accessibility and traditional culinary preferences. Economic factors also contribute to these patterns, as wealthier nations, such as Luxembourg (27.7%), show a higher likelihood of affording seafood, often regarded a premium food choice. Additionally, health-conscious populations, particularly in Northern Europe, tend to prioritise fish for its perceived nutritional benefits.

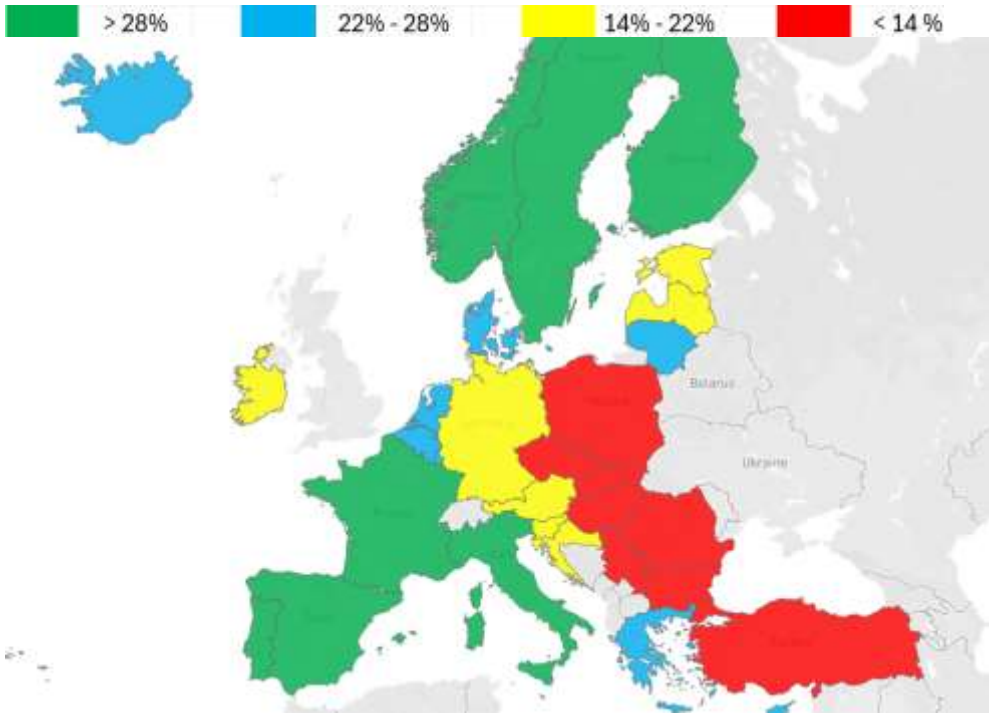

Figure no. 2. Proportion of fish and seafood in total meat consumption
Source: authors' calculations in Tableau

These patterns align with the findings of Kearney (2010), who emphasises the role of economic development and globalisation in shaping food consumption trends. Countries with higher purchasing power and access to global food markets generally display more diverse diets, including a greater emphasis on seafood. Furthermore, the results support Feldmann and Hamm (2015), who highlight that consumer preferences for locally sourced and sustainable foods influence diet trends. The strong reliance on fish in the northern and coastal regions aligns with their findings, suggesting that regional food traditions and environmental

awareness drive the demand for seafood. While cultural heritage and geographical factors clearly shape fish consumption, purchasing power and health consciousness also contribute to the significant variation in seafood intake across Europe.

3.2. Regression results and discussions

The regression analysis (Table no. 2) highlights several key trends in how economic, lifestyle, and cultural factors influence food consumption choices. GDP_PPP significantly increases the consumption of vegetables (coefficient = 8.339, $p<0.01$) and fruits (coefficient = 3.558, $p<0.01$) consumption, suggesting that greater purchasing power allows individuals to afford and prioritise healthier foods. However, the relationship between sports participation and vegetable consumption is slightly negative (coefficient = -0.093, $p<0.1$), potentially indicating that active individuals diversify their diets with foods rich in protein and energy dense. For fruit consumption, sports participation has a significant positive effect (coefficient = 0.373, $p<0.01$), possibly because physically active individuals seek fruit for its vitamins and antioxidants. In the case of meat consumption, poultry consumption does not show significant associations with the variables examined, strengthening its status as a versatile protein source in different cultures and income levels. Pork consumption is negatively influenced by sports participation (coefficient = -0.142, $p<0.01$) and GDP_PPP (coefficient = -1.099, $p<0.01$), suggesting that more physically active and wealthier individuals may prefer leaner meat options. Cultural dimensions also play a role, as individualistic societies (IDV coefficient = -0.108) and those with long-term orientation (LTO coefficient = -0.135) consume less pork, possibly due to ethical concerns or long-term health considerations. On the contrary, beef consumption is positively influenced by sports participation (coefficient = 0.098, $p<0.01$), GDP_PPP (coefficient = 0.687, $p<0.01$), and LTO (coefficient = 0.182, $p<0.01$), suggesting that active individuals and wealthier populations view beef as a source of high quality proteins. Fish consumption follows a similar pattern, with sports participation (coefficient = 0.081, $p<0.01$), GDP_PPP (coefficient = 0.146, $p<0.01$), IDV (coefficient = 0.133, $p<0.05$), and LTO (coefficient = 0.121, $p<0.05$) all positively influencing fish intake, reinforcing the perception of fish as a sustainable and health conscious diet choice. Across models, GDP_PPP and SPORT consistently emerge as key drivers of food consumption patterns, while cultural factors such as IDV, LTO, and UAI shape specific dietary preferences.

Table no. 2. The effects of determinants on the structure of food consumption: random effects panel estimates (coefficients and z-stat in parentheses)

Dep. Variable	FREQ VEGCONS	FREQ FRUCONS	POULTRY_TMC	PORK_TMC	BEEF_TMC	FISH_TMC
SPORT_FRQ	*-0.093 (-1.89)	***(0.373) (2.63)	0.006 (0.10)	***-0.142 (-4.39)	***0.098 (3.46)	***0.081 (2.64)
GDP_PPP	***8.339 (20.7)	***(3.558) (4.46)	-0.203 (-0.62)	***-1.099 (-6.02)	***0.687 (4.24)	***0.146 (6.63)
IDV	0.052 (1.09)	0.068 (0.26)	0.003 (0.04)	**-0.108 (-2.01)	0.035 (0.78)	**0.133 (2.56)
LTO	-0.016 (-0.32)	0.193 (0.67)	-0.127 (-1.59)	**-0.135 (-2.16)	***0.182 (3.77)	**0.121 (2.14)

Dep. Variable	FREQ VEGCONS	FREQ FRUCONS	POULTRY _TMC	PORK _TMC	BEEF _TMC	FISH _TMC
UAI	0.070	*0.469	0.070	0.059	-0.068	-0.027
	(1.57)	(1.86)	(0.99)	(1.08)	(-1.61)	(-0.54)
Constant	***-19.2	**-52.54	***25.92	***65.28	-0.883	-5.788
	(-3.68)	(-2.11)	(3.67)	(12.1)	(-0.21)	(-1.18)
R^2 within	0.915	0.778	0.016	0.883	0.782	0.863
R^2 between	0.217	0.138	0.115	0.650	0.609	0.600
R^2 overall	0.327	0.140	0.115	0.650	0.610	0.601

Note: ***, **, * significant at 1%, 5%, 10%

Source: own calculations in STATA 18

These findings align with Kearney (2010), who highlights the role of economic growth in dietary diversification, showing that wealthier populations have greater access to a variety of foods, including fruits, vegetables, and high-quality protein sources. The negative effect of GDP_PPP on pork consumption also supports Rana and Paul (2017), who found that rising incomes often correlate with a shift toward healthier and organic food choices, potentially reducing the dependence on processed or high-fat meats. The significant influence of sports participation on dietary preferences is consistent with Meyer and Reguant-Closa (2017), who emphasise that athletes and physically active individuals tend to prioritise foods that align with their performance and recovery needs, including lean meat and nutrients-dense foods such as fruits and fish. The role of cultural dimensions such as IDV and LTO in shaping meat and fish consumption is in line with De Mooij and Hofstede (2011), who argue that individualistic societies are more likely to make diet choices based on personal health concerns, while long-term-oriented cultures prioritise sustainable and nutritious foods. Lastly, the findings resonate with Feldmann and Hamm (2015), who discuss how consumer preferences for local and environmentally sustainable food products are shaped by cultural and economic factors, explaining why wealthier, long-term-oriented societies may favour fish over other meats. Together, these comparisons highlight how economic status, lifestyle choices, and cultural values interact to determine food consumption patterns in different regions.

Conclusions

Regression analysis highlights how economic, lifestyle, and cultural factors shape food consumption patterns in European countries. Higher purchasing power consistently increases the consumption of healthier and premium foods, such as vegetables, fruits, beef, and fish, reflecting a preference for quality and health-conscious choices. Regular physical activity, while promoting the consumption of fruits and fish, appears to reduce the preference for pork due to its higher fat content. Cultural indicators, such as individualism (IDV) and long-term orientation (LTO), influence preferences for certain foods, with more individualistic and future-oriented societies favouring options such as fish and beef for their perceived health and sustainability benefits. In general, the analysis underscores the interplay of economic capacity, active lifestyles, and cultural values in the promotion of dietary habits.

The study has *potential limitations* due to its relatively small sample of countries and time points, which may not fully capture long-term trends or broader global patterns. Specific regional dietary traditions and cultural factors unique to different parts of the world might

limit the generalisability of the findings to non-European contexts. Seasonal and regional variations in food availability, particularly for fruits and fish, can also influence the results, adding a layer of complexity not fully addressed. Additionally, differences in economic development within the sample countries could mask nuanced relationships between variables. These factors suggest caution when extending the study's conclusions beyond the analysed context.

Future research could expand the geographic scope to include countries from other regions, allowing comparisons between European and non-European dietary patterns. Longitudinal studies covering more time points would help identify long-term trends and the evolving impact of economic and cultural factors on food consumption. Investigating the role of additional variables, such as environmental sustainability or government policies, could provide a more comprehensive understanding of dietary choices. Finally, incorporating data on seasonal and regional food availability could refine insights into consumption variability and its determinants.

The findings highlight key *policy implications* for stakeholders in the food market, offering actionable recommendations. Economic and cultural changes require food chain actors to align with evolving consumer preferences, particularly for healthier and premium products. Targeted policies should promote sustainable agriculture, nutrition education, and fiscal incentives such as subsidies for organic farming and reduced VAT on fresh produce. Technological advances, including digital marketing and supply chain innovations, are crucial. Governments should support blockchain for traceability, e-commerce for local producers, and research on smart food production. Public-private partnerships can improve efficiency and reduce waste. Sustainability remains critical, requiring stricter environmental standards, incentives for plant-based alternatives, and responsible aquaculture policies. Consumer awareness campaigns can encourage sustainable eating choices. To ensure resilience, SMEs need support in diversifying products, strengthening local supply chains, and accessing new markets. Financial incentives for sustainability and innovation can enhance adaptability. Effective marketing and labelling systems must provide transparency on the origin, nutrition, and environmental impact of food. Aligning food policies with economic, cultural, and technological trends is the key to a resilient, sustainable, and health-conscious food market. A combination of fiscal incentives, regulations, technological investments, and consumer education will drive sustainable consumption patterns across Europe.

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Enhancing the Striking Angle of Inside-Foot Passes: An Educational Approach for Fifth and Sixth-Grade Students

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Abstract: *This study investigates the impact of structured training programs on improving the striking angle of inside-foot passes among fifth and sixth-grade students. The research contextualizes its findings within the broader scientific literature on biomechanics, motor learning, and youth sports development. Forty students aged 10–12 participated in a six-week intervention, divided into experimental and control groups. The intervention incorporated targeted exercises, bilateral play, and biomechanical analysis using Kinovea software. Statistical analysis revealed significant improvements in the experimental group (p=0.00). This study underscores the necessity of structured pedagogical approaches in physical education to enhance technical skill acquisition and recommends further research on long-term effects and advanced biomechanical assessments.*

Keywords: *striking angle, technical complexes, Kinovea, football, biomechanics.*

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Introduction

Football is not only the most popular sport globally but also serves as an essential component of physical education programs in schools (Popescu et al., 2023). Its dynamic nature promotes physical fitness, teamwork, discipline, and social interaction among students (Chunoh et al., 2020). Within the vast array of skills required in football, techniques such as the inside-foot pass are fundamental to effective game-play (Fatmala et al., 2024). Mastering this skill is crucial as it can significantly impact a player's contribution to their team and enhance their overall enjoyment of the sport (Setyawan, 2024; Alesi et al., 2022). This research's purpose is to discover the outcomes of specific exercises and instructional strategies targeted at improving the striking angle for the inside foot pass among fifth and sixth-grade students.

Recent observations highlighted the reality that many young players, particularly those in the formative years of football, ages 10 to 12, often exhibit neglect towards the development of essential techniques, such as the inside-foot pass (Teoldo et al., 2021). This neglect can result in a lack of effective performance during games and ultimately diminish the overall enjoyment of the sport for these young athletes (de León Rodríguez et al., 2024). Mastery of the inside-foot pass is critical for facilitating accurate and powerful passes, which can lead to successful plays and greater team cohesion (Săndoi et al., 2023).

Through this research, we will explore how targeted training interventions influence students' ability to execute this crucial skill efficiently. By assessing the changes in performance before and after a structured training program, this study aims to establish whether a systematic approach to teaching football techniques can lead to significant improvement in students' skill levels (Krustrup et al., 2016).

The study encompasses a variety of exercises specifically designed to enhance the mechanics of passing with the inside foot. Evaluating students' performance in a controlled environment allows us to measure the effectiveness of these training methods quantitatively (Caracaleanu & Caracaleanu, 2019). This investigation is not solely about improving athletic performance; it also provides insights into effective pedagogical strategies in physical education (Li & Mateos, 2022).

This research is timely, considering the growing emphasis on youth sports development and the importance of foundational skills in children's physical education programs.

Literature review

Football passing mechanics have been extensively studied, with researchers emphasizing joint coordination, muscle activation, and biomechanical efficiency. Kellis & Katis (2007) highlight the importance of joint synchronization in executing powerful and accurate passes. Similarly, Tamura et al. (2023) found that proprioceptive training significantly enhances movement efficiency and passing accuracy.

Nunome et al. (2006) analyzed the segmental dynamics of side-foot and instep kicks, concluding that proper balance and stability significantly impact passing precision. Lees et al. (2009) further investigated pelvic motion and its effect on soccer kicking accuracy, revealing that stabilizing the pelvis during foot contact enhances pass consistency. Ahsan (2018) examined angular kinematics in soccer kicks, concluding that optimized striking angles lead to greater passing efficiency.

Additional studies have explored the pedagogical aspects of football training. Krustrup et al. (2016) emphasized the role of small-sided games in improving technical skill acquisition, while Li & Mateos (2022) discussed the influence of structured youth training on player development. Collectively, these studies highlight the need for scientifically designed interventions to refine technical execution in youth footballers.

Moreover, recent advancements in biomechanical research indicate that the use of motion analysis software, such as Kinovea, provides valuable insights into movement efficiency, allowing for precise adjustments in training programs (Carlsson et al., 2019). Teoldo et al. (2021) advocate for the integration of real-time video analysis in coaching methodologies, emphasizing that it facilitates better player awareness and skill refinement. In addition, Săndoi et al. (2023) highlight that targeted interventions, such as repetition-based drills and biomechanical feedback, significantly improve motor learning and execution in football-specific skills.

By synthesizing these studies, it becomes evident that targeted biomechanical training is essential for refining the inside-foot pass technique. This study builds on these foundations by implementing a structured training regimen specifically designed to enhance striking angles and overall passing accuracy among young players.

Methodology

Forty students aged 10–12 participated in the study, equally divided into experimental and control groups. Gender balance was maintained to mitigate physiological differences in performance. Participants were screened

for prior football experience, and baseline assessments included anthropometric measurements (height and weight).

Baseline assessments were conducted to measure passing accuracy using Kinovea software, a tool for biomechanical motion analysis. Kinovea software enabled precise tracking of foot positioning, impact angles, and pass trajectory, providing quantitative insights into technical performance. The experimental group underwent a structured six-week training intervention, while the control group engaged in standard physical education activities.

The training intervention included:

- **Wall Passes:** Enhancing passing consistency through repetitive ball contact with a wall.
- **Partner Drills:** Reinforcing accuracy and ball control through paired passing exercises.
- **Dynamic Target Passing:** Simulating in-game scenarios with moving targets to improve precision.
- **Small-Sided Games:** Encouraging real-time decision-making and skill application in a competitive setting.

Post-intervention assessments mirrored initial evaluations to measure improvements in striking angles and passing accuracy.

The study was approved by an institutional ethics committee. Parental consent and participant assent were obtained, ensuring ethical compliance. Participants were informed of their right to withdraw without consequence. Data confidentiality and safety protocols were maintained throughout the study.

Additionally, the study complied with the ethical guidelines established by international sports research bodies. The data collection process was conducted with minimal intrusion, ensuring that participants' privacy was respected. All recorded footage used for motion analysis was anonymized before analysis.

Findings

Normal distribution of data test was verified through the Shapiro-Wilk test. Results indicated that the data were normally distributed, as the p-value for all variables exceeded 0.05.

Table 1 – Results of the paired sample t-test for each of the groups (E.G. and C.G.) between the initial (I.M.) and final (F.M.) measurements

	Mean	N	S.D.	t	df	p
Striking Angle E.G. F.M.	1.81°	20	1.02	-8.00	19	0.00
Striking Angle E.G. I.M.	5.40°	20	1.70			
Striking Angle C.G. F.M.	5.99°	20	3.97	0.92	19	0.37
Striking Angle C.G. I.M.	5.09°	20	1.75			

A paired samples t-test was performed to compare the Striking Angle values between the initial and final E.G. measurement conditions. A statistically significant difference was found between the values of Striking Angle E.G. I.M. (M=5.40°, SD=1.70) and Striking Angle E.G. F.M. (M=1.81°, SD=1.02); t(19)=-8.00, p=0.00. These results suggest that drills, technical complexes and bilateral thematic play had a significant impact on improving lats striking angle from baseline to final measurements.

We performed the same paired samples t-test to compare the hitting angle values between the baseline and final C.G. measurement conditions. There was no statistically semi-significant difference between the C.G. I.M. (M=5.09°, SD=1.75) and C.G. F.M. (M=5.99°, SD=3.97) values, t(19)=0.92, p=0.37.

Table 2 – Results of the independent sample t-test for each of the measurements (I.M. and F.M.) between the experimental (E.G.) and control (C.G.) groups

	Group	N	Mean	S.D.	t	df	p	Mean Diff.
Striking Angle I.M.	E.G.	20	5.40°	1.70	0.56	38	0.58	0.31°
	C.G.	20	5.09°	1.75				
Striking Angle F.M.	E.G.	20	1.81°	1.02	-4.56	38	0.00	-4.18°
	C.G.	20	5.99°	3.97				

The independent samples t-test was used to compare the values of the angle of impact under the initial measurement conditions of the two groups. No statistically significant difference was found between the values of E.G. (M=5.40°, SD=1.70) and C.G. (M=5.09°, SD=1.75); t(38)=0.56, p=0.58. These results suggest that the two groups are homogeneous in terms of the values obtained at the time of the first measurement.

We performed the independent samples t-test to compare the values of the angle of impact in the final measurement conditions of the two groups. A statistically semi-significant difference was found between the

E.G. (M = 1.81°, SD = 1.02) and C.G. (M = 5.99°, SD = 3.97) values; $t(38)=-4.56$, $p = 0.00$. These results suggest that E.G. outperformed C.G., so the drills, technical complexes and bilateral play had the desired effect at the beginning of the research.

Discussions

The findings of this study reveal that targeted training interventions significantly influenced the striking angles in the experimental group, with a notable reduction in the striking angle F.M. (mean difference: -4.18°, $p < 0.05$) compared to the control group. This outcome suggests that the structured drills employed were effective in refining this technical element of the soccer inside foot strike. However, the striking angle I.M. showed no significant changes, likely due to the inherently smaller initial variation between groups.

These results align with findings from other research into soccer kicking biomechanics. For instance, Kellis and Katis (2007) emphasize the importance of joint coordination in achieving precision and power during side-foot kicking. Their study highlights that efficient neuromuscular control is pivotal for accurate execution, which resonates with the improvements observed in our experimental group following the intervention. Similarly, Tamura et al. (2023) noted that targeted training can improve joint stiffness and coordination, critical components for stabilizing the supporting leg during the kicking motion, further supporting the importance of focused practice in enhancing technical skills.

Another relevant study by Lees et al. (2009) examined the role of pelvic motion in the accuracy of soccer kicks, reporting that a stable pelvis during support foot contact is crucial for precise ball impact. Although our study primarily focused on the foot strike angle, the structured training likely contributed to a more controlled overall kicking posture, indirectly influencing accuracy and efficiency.

The practical implications of this research are clear: targeted exercises, such as those involving wall passes, bilateral drills, and small-sided games, can significantly refine technical skills, particularly the inside foot pass. Coaches and educators should incorporate these drills to improve not only physical execution but also players' confidence and teamwork. Furthermore, findings from studies like Tamura et al. (2023) and Nunome et al. (2002) stress the importance of biomechanical analysis in tailoring training programs to the specific needs of players, including those with chronic conditions like ankle instability.

The substantial improvement in the experimental group's performance underscores the critical role of structured training in developing foundational sports skills, particularly in soccer. This aligns with findings by Carlsson et al. (2019), who observed that a short, technique-intensive training period significantly enhanced side-foot kick performance among elite female soccer players. Their study emphasized the value of repeated, focused drills in refining technical execution, which parallels the positive effects of the training interventions applied in our study. Similarly, Ahsan (2018) highlights the importance of angular kinematics, particularly during the impact phase of the inside kick, in optimizing performance. This suggests that our structured drills may have contributed to better coordination and mechanics, thereby improving striking angles and execution.

Several limitations must be acknowledged, despite the promising outcomes. The generalization of these results are limited by the relatively small sample size and short intervention duration. Future studies should consider larger and more diverse populations, along with longitudinal designs, to evaluate the sustainability of these technical improvements. Additionally, integrating motion capture systems, as demonstrated by Nunome et al. (2006), could provide deeper insights into biomechanical adjustments during training and gameplay.

Expanding performance metrics to include other kinematic and kinetic variables, such as joint moments and foot swing velocity, could also yield a more comprehensive understanding of the effects of training interventions. Exploring these variables in different demographic groups, such as younger or less experienced players, would further validate and extend the applicability of these findings.

Conclusions

Based on the analysis of the collected data and the interpretation of the results, several key conclusions can be drawn that align with the initial objectives of this study. The findings indicate that the striking angle of the ball, when using the inside of the foot (with the instep), can be improved through the use and practice of wall-passing exercises, paired drills, technical complexes, and bilateral games with specific themes.

The use of a select number of well-chosen exercises, repeated multiple times, proves to be not only a current trend but also an effective method for developing technical skills in detail. Mastery of technical executions at higher speeds and in adversarial conditions enhances the fluidity of play through simple and efficient actions. The striking angle in

passing techniques, influenced by repeated exercises, technical complexes, and themed games, became more precise, alongside improvements in execution speed, ball speed, and player movement.

Additionally, the students' determination to succeed and improve their passing technique, particularly with the inside of the foot, was evident. The importance of altruism in football was also emphasized, with bilateral games playing a crucial role in fostering teamwork and cooperative play.

The results obtained from the experimental group confirm the hypothesis of the study: a noticeable modification in the striking angle of the inside foot pass was observed among students following the application of wall-passing exercises, paired drills, and thematic bilateral games.

Nevertheless, further research is needed to explore the long-term effects of these exercises, technical complexes, and bilateral games on a larger sample size. This would help establish a more comprehensive understanding of the impact of these interventions over time.

Methodological recommendations include ensuring that students in the educational process are provided with the necessary equipment and materials that meet at least the minimum requirements of the lesson objectives. Furthermore, monitoring the health and well-being of students is essential to prevent injury during training.

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THE INFLUENCE OF BALL ELASTICITY ON THROWING SPEED AND GRIP STRENGTH IN FEMALE HANDBALL PLAYERS

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ABSTRACT. Introduction: This study examines ball elasticity's impact on throwing speed and palmar strength in female handball players. **Objective:** We hypothesize that ball elasticity influences throwing speed and palmar strength. **Methods:** Nine players were grouped by ball elasticity and underwent grip strength measurements, throws, and exercise. **Results**: Exercise had no significant throwing speed effect; palmar strength decreased. Elasticity showed minimal differences, but hard balls slightly impacted post-exercise speed. **Conclusion:** Exercise impacted palmar strength, but not throwing speed. Elasticity subtly affected post-exercise speed.

Keywords: *Ball Elasticity, Throwing Speed, Palmar Strength, Handball, Exercise-Induced Fatigue*

REZUMAT. ***Influența elasticității mingii asupra vitezei de aruncare și a forței de strângere a mâinii la jucătoarele de handbal.*** **Introducere**: Acest studiu examinează impactul elasticității mingii asupra vitezei de aruncare și a forței palmare la jucătoarele de handbal. **Obiectiv**: Emitem ipoteza că elasticitatea mingii influențează viteza de aruncare și puterea palmară. **Metode**: Nouă jucători au fost grupați în funcție de elasticitatea mingii și au fost supuși măsurătorilor de forță de prindere, aruncări și exerciții. **Rezultate**: Exercițiul nu a avut un efect semnificativ asupra vitezei de aruncare; puterea palmară a scăzut. Elasticitatea a arătat diferențe minime, dar mingile dure au afectat ușor viteza post-exercițiu.

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Concluzie: Exercițiul a afectat forța palmară, dar nu viteza de aruncare. Elasticitatea a afectat subtil viteza post-exercițiu.

***Cuvinte cheie**: elasticitate a mingii, viteză de aruncare, forță palmară, handbal, oboseală indusă de exercițiu*

INTRODUCTION

Handball is a dynamic and physically demanding team sport that requires a unique combination of technical skills, physical attributes, and strategic thinking (Gandevia,2001; Steib et al.,2013). As one of the most popular team sports worldwide, handball garners significant attention, especially in its female variant. The success of a handball team hinges upon the prowess of its players in various aspects, such as throwing accuracy, strength, and overall hand function (Barbieri et al., 2017). This study delves into a comprehensive examination of the female handball player model, with a specific focus on two pivotal factors: throwing strength and palmar dynamometry.

The act of throwing in handball involves intricate biomechanics and muscular coordination. The force exerted during a throw is a critical determinant of the accuracy and speed of the projectile (Thorlund et al., 2008). Furthermore, a player's ability to maintain consistent throwing strength throughout a match influences their overall performance and the team's success. This study aims to unravel the nuances of throwing strength in female handball players, considering factors such as muscular development, technique, and training regimens (Foster et al., 2001).

In addition to throwing strength, palmar dynamometry, which assesses grip strength, plays a pivotal role in a handball player's overall performance. A player's grip strength can significantly impact their ability to control the ball, fend off opponents, and engage in various game-related activities (Nocella et al. 2011; Fitts, 1994). Understanding the relationship between grip strength and handball performance is crucial for optimizing training programs and enhancing player capabilities.

This article delves into a theoretical exploration of the key components underpinning the female handball player model (Noakes, 2000). By investigating throwing strength and palmar dynamometry, we aim to provide valuable insights that can inform training methodologies, player selection criteria, and performance evaluation metrics (Beaulieu, 2008). As the sport of handball continues to evolve, bridging the gap between theoretical understanding and practical application is essential for nurturing successful female handball players and elevating the overall quality of the game.

HYPOTHESIS

We postulate that the elasticity of the ball used in female handball significantly influences both throwing speed and palmar strength. Specifically, we anticipate that the exercise-induced fatigue protocol will yield a reduction in palmar strength measurements, reflecting the temporary muscular fatigue resulting from the exercises. Regarding throwing speed, we hypothesize that the exercise-induced fatigue will lead to a decrease in throwing speed due to the compromised muscular strength and coordination resulting from fatigue.

MATERIALS AND METHODS

Participants

Nine female handball players, from C.S. Universitatea Cluj, each with varying levels of experience, were recruited for the study. Participants were divided into three groups, with three participants in each group. The groups were distinguished based on the type of ball used: soft, medium, and hard elasticity. Prior to participation, all participants provided informed consent, and their demographic and anthropometric information was collected.

Equipment

1. **MbientLab MetaMotionS (Accelerometer):** The MbientLab MetaMotionS accelerometer is a sophisticated wearable device designed to measure and record acceleration, motion, and orientation data. This compact and lightweight sensor is seamlessly integrated into the study to capture the nuanced movements and actions of female handball players. The accelerometer's advanced technology enables the precise quantification of throwing motions, aiding in the assessment of throwing strength and technique. Through its wireless connectivity, the MetaMotionS facilitates real-time data transmission to a connected device, allowing researchers to analyze and interpret the intricate dynamics of the players' movements during handball activities.
2. **Palmar Dynamometer:** The palmar dynamometer is an essential tool used for assessing grip strength — the force exerted by the hand's muscles while gripping an object. In this study, the palmar dynamometer is employed to measure the hand strength of female handball players. By quantifying grip strength, researchers can gain insights into the players' hand function, which directly influences their ability to control the ball, fend off opponents, and

engage in various game-related actions. The dynamometer provides accurate and standardized measurements, ensuring consistency and reliability in evaluating the players' hand strength. We used a hand-held spring activated dynamometer from Ralondbey.

3. **Rubber Balls:** Rubber balls serve as the primary projectiles in handball and are utilized for various throwing exercises and measurements. These standardized rubber balls replicate the size, weight, and texture of the balls used in official handball matches. Throughout the study, participants engage in controlled throwing exercises using the rubber balls. These exercises not only facilitate the evaluation of throwing strength but also enable researchers to analyze throwing accuracy and technique. By using standardized rubber balls, the study ensures uniformity in the testing conditions and enhances the validity of the findings. We have used standard handball balls size 3.

4. **Stopwatch:** The stopwatch is an indispensable timing device used to precisely measure the duration of various handball-related activities. Researchers employ the stopwatch to record the time taken for actions such as throwing a rubber ball, completing specific drills, and performing agility exercises. Accurate timing is crucial for assessing the speed of throws, reaction times, and overall performance. The stopwatch contributes to the collection of quantitative data, allowing researchers to analyze the temporal aspects of players' actions and correlate them with other measured parameters.

These equipment components synergistically contribute to the comprehensive examination of female handball players' capabilities. The MetaMotionS accelerometer captures nuanced movement patterns, the palmar dynamometer quantifies grip strength, rubber balls replicate game-like conditions, and the stopwatch ensures accurate timing — combined, these tools empower researchers to uncover valuable insights into the intricate dynamics of female handball performance.

Procedure

1. **Baseline Measurements:** Before engaging in any physical activities, participants' baseline grip strength was assessed using the palmar dynamometer. Each participant performed three maximum-effort grip squeezes with each hand, alternating between hands. The average grip strength for each hand was recorded.

2. **Group Allocation:** Participants were randomly assigned to one of the three groups based on the elasticity of the ball they would use: soft, medium, or hard.

3. **Pre-Exercise Accelerometer Measurements:** Participants were equipped with the MetaMotionS accelerometer, securely fastened to their throwing arm. Each participant from each group performed 7-meter throws using their designated ball elasticity. Two trials of 7-meter throws were conducted for each participant, and the accelerometer recorded the kinematic data of each throw.
4. **Exercise Protocol:** After the pre-exercise measurements, participants engaged in the palmar flexion exercise protocol using the designated ball elasticity. They completed 10 isometric repetitions of the palmar flexion exercise, gripping the ball as forcefully as possible.
5. **Post-Exercise Accelerometer Measurements:** Following the exercise protocol, participants repeated the 7-meter throws using their designated ball elasticity. Similar to the pre-exercise phase, two trials of 7-meter throws were performed for each participant, and the accelerometer captured the kinematic data of each throw.
6. **Post-Exercise Palmar Dynamometer Measurements:** Immediately after the post-exercise throws, participants' grip strength was measured once again using the palmar dynamometer. Three maximum-effort grip squeezes were performed with each hand, alternating between hands. The average grip strength for each hand was recorded.
7. **Data Analysis:** The accelerometer data from the 7-meter throws were analyzed to evaluate throwing strength, technique, and consistency within each elasticity group. Grip strength measurements before and after the exercise protocol were compared for each group to assess the impact of the exercise on participants' hand strength.

Statistical Analysis

Descriptive statistics (mean, standard deviation) were calculated for grip strength measurements and accelerometer data within each group. Paired t-tests were conducted to analyze grip strength changes before and after the exercise protocol within each group. Analysis of variance (ANOVA) was employed to assess any significant differences in accelerometer data between pre-exercise and post-exercise throwing trials within each group. All the statistical analysis has been done for a statistical significance threshold of .05 (p value).

Ethical Considerations

The study adhered to ethical guidelines and received approval from the Faculty of Physical Education and Sport, Babeş-Bolyai University. All participants provided informed consent, and their privacy and data security were ensured throughout the study.

By incorporating different ball elasticities and grouping participants accordingly, this methodology aims to explore the potential impact of ball elasticity on grip strength, throwing dynamics, and overall performance among female handball players.

RESULTS

Table 1. Paired sample t-test between initial and final measurement conditions

		Mean	N	Std. Deviation	t	df	Sig. (2-tailed)
Pair 1	ThrowSpeedMax_M2	84.67	9	6.34	.679	8	.517
	ThrowSpeedMax_M1	82.75	9	7.73			
Pair 2	ThrowSpeedMin_M2	4.98	9	1.12	-1.156	8	.281
	ThrowSpeedMin_M1	5.37	9	.95			
Pair 3	PalmStrength_M2	37.22	9	9.55	-4.163	8	.003
	PalmStrength_M1	50.22	9	16.76			

Table 2. Independent sample t-test between soft and medium ball conditions

	Group	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)
ThrowSpeedMax_M1	1	3	84.65	4.30	.514	4	.634
	2	3	82.58	5.51			
ThrowSpeedMin_M1	1	3	5.07	1.39	-.648	4	.553
	2	3	5.68	0.88			
ThrowSpeedMax_M2	1	3	87.01	2.77	.067	4	.950
	2	3	86.60	10.31			
ThrowSpeedMin_M2	1	3	5.34	1.43	-.001	4	.999
	2	3	5.34	0.84			
PalmStrength_M1	1	3	46.00	25.12	-.421	4	.695
	2	3	52.67	11.02			
PalmStrength_M2	1	3	35.00	13.23	-.149	4	.889
	2	3	36.33	8.08			

Table 3. Independent sample t-test between medium and hard ball conditions

	Group	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)
ThrowSpeedMax_M1	2	3	82.58	5.51	.187	4	.861
	3	3	81.02	13.42			
ThrowSpeedMin_M1	2	3	5.68	0.88	.463	4	.667
	3	3	5.36	0.81			
ThrowSpeedMax_M2	2	3	86.60	10.31	1.015	4	.368
	3	3	80.40	2.35			
ThrowSpeedMin_M2	2	3	5.34	0.84	1.352	4	.248
	3	3	4.27	1.07			
PalmStrength_M1	2	3	52.67	11.02	.054	4	.959
	3	3	52.00	18.19			
PalmStrength_M2	2	3	36.33	8.08	-.537	4	.620
	3	3	40.33	10.07			

Table 4. Independent sample t-test between soft and hard ball conditions

	Group	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)
ThrowSpeedMax_M1	1	3	84.65	4.30	.447	4	.678
	3	3	81.02	13.42			
ThrowSpeedMin_M1	1	3	5.07	1.39	-.318	4	.766
	3	3	5.36	0.81			
ThrowSpeedMax_M2	1	3	87.01	2.77	3.150	4	.035
	3	3	80.40	2.35			
ThrowSpeedMin_M2	1	3	5.34	1.43	1.030	4	.361
	3	3	4.27	1.07			
PalmStrength_M1	1	3	46.00	25.12	-.335	4	.754
	3	3	52.00	18.19			
PalmStrength_M2	1	3	35.00	13.23	-.556	4	.608
	3	3	40,33	10,07			

DISCUSSION

This study investigated the influence of ball elasticity on throwing speed and palmar strength in female handball players, offering insights into performance parameters under varying conditions. The results contribute to understanding the interplay between equipment characteristics, athletic performance, and fatigue, providing a foundation for further investigation.

The analysis of throwing speed, encompassing both maximum and minimum values, revealed no statistically significant differences between pre-exercise (M1) and post-exercise (M2) measurements (e.g., for ThrowSpeedMax: M1 Mean = 82.75, SD = 7.73; M2 Mean = 84.67, SD = 6.34). These results indicate that the specific exercise protocol did not adversely affect throwing speed, suggesting that well-trained athletes possess adaptations that mitigate the impact of short-term fatigue. This aligns with studies such as those by Raeder et al. (2015).

In contrast, a significant reduction in palmar strength was observed following the exercise protocol (M1 Mean = 50.22, SD = 16.76; M2 Mean = 37.22, SD = 9.55). This outcome underscores the effectiveness of the protocol in inducing muscle fatigue, particularly in the muscles responsible for grip strength. Similar findings were reported by Jöris et al. (1985) and Tuquet et al. (2020), who observed declines in grip strength following high-intensity handgrip exercises in athletes. This reduction emphasizes the importance of recovery strategies and targeted strength training to enhance grip endurance.

The study compared soft, medium, and hard ball conditions, revealing no statistically significant differences in most parameters across the groups (e.g., ThrowSpeedMax_M1; PalmarStrength_M1). These findings suggest that ball elasticity does not play a dominant role in influencing throwing speed or grip strength during standard conditions. Consistent with the work of Manchado et al. (2020), external equipment factors like ball elasticity may have a smaller effect compared to biomechanical and physiological variables intrinsic to the athlete.

Interestingly, a significant difference was observed in ThrowSpeedMax_M2 when comparing soft and hard balls (Soft Mean = 87.01, SD = 2.77; Hard Mean = 80.40, SD = 2.35). This finding suggests a nuanced interaction between ball elasticity and muscle fatigue, potentially due to differences in energy transfer and grip dynamics. It aligns with studies by Mascarin et al. (2017), which emphasize the importance of equipment properties in specific performance scenarios. The interaction between fatigue and ball characteristics warrants further exploration to determine its implications for match play and injury prevention.

These findings provide valuable insights for optimizing training and equipment in handball. Coaches should prioritize grip-specific endurance training and recovery strategies to address fatigue-related declines in performance. While ball elasticity had limited impact under standard conditions, its role in fatigue scenarios suggests that equipment design could be tailored to support athletes during extended play.

Future research should expand the sample size and investigate the biomechanical and neuromuscular mechanisms underlying these interactions. Incorporating advanced technologies such as motion capture and electromyography could provide a deeper understanding of how ball elasticity influences performance. Additionally, longitudinal studies could explore the long-term effects of training with different ball types on athlete development and injury risk.

This study highlights that while ball elasticity has minimal impact on throwing speed and grip strength under standard conditions, its influence becomes significant under fatigue. These findings contribute to a nuanced understanding of performance determinants in handball and underscore the importance of integrating equipment considerations into training and competition strategies.

CONCLUSION

In conclusion, the study's results shed light on the intricate interplay between ball elasticity, throwing speed, and palmar strength among female handball players. While the exercise protocol effectively induced muscle fatigue, it did not significantly impact throwing speed. Additionally, ball elasticity exhibited minimal influence on the parameters considered, with only a subtle differentiation observed between soft and hard balls in the context of post-exercise maximal throwing speed. These findings underscore the complexity of factors influencing handball performance and advocate for continued research to comprehensively understand the multifaceted nature of player dynamics.

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Developed Jumping Power Relation with other Neuromuscular Coefficients from the Mgm-15 Jump Carpet

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Abstract

Background. We want to determine if a specific sports training program could improve neuromuscular and performance indices in female athletes measuring their jump power players **Subjects and Methods**. A number of 20 female basketball players with the ages between 9 and 11 years old participated in this study. We've used the MGM-15 Jump Carpet for evaluating the jumping power and other neuromuscular coefficients. **Results**. There was a significant statistical correlation between the energetic variability coefficient (EVC) and structural variability coefficient (SVC). There was a significant linear regression between the jump power and force-speed asymmetry. **Conclusion.** Both the structural and energetic coefficients refer to the same aspect of the neuromuscular process and therefore it was natural to identify a correlation. The linear regression discovered between the power output and the force-speed asymmetry can indicate that there is an impact over the rate of variance of the asymmetry with regards to the power output.

Keywords: MGM-15, basketball, power output, neuromuscular, force-speed asymmetry.

Nomenclature

Avg_UP – average power output
EVC – energetic variance coefficient
SVC – structural variance coefficient
FS_Asym – force – speed asymmetry

Introduction

Many training programs have been developed to improve player fitness and skill and hypothetically prevent injuries. Investigations vary considerably in the selection of subjects, duration of training, exercises and drills performed, and outcome measures. Only one study to date assessed performance indices in female basketball players using the Sports metrics training program (Wilkerson, GB, et.al., 2004.).

A small group of female collegiate basketball players obtained significant improvements in hamstring peak torque ($p = 0.008$), which were not found in the control group of players. Development of hamstrings strength is believed to be

one important factor in preventing knee ligament injuries in female athletes (Alentorn-Geli, E., Myer, G., et. al., 2009.)

Another study says that Sports metrics neuromuscular training for female athletes involved in a variety of sports 15 years ago (Hewett T., Lindenfeld T., et. al., 1999) and noted occasional problems with player compliance with the program. The training consisted of a dynamic warm-up, jump training, strength training, and flexibility. Over time, players and coaches requested that the program be modified to include additional sport-specific exercises and drills designed to improve speed, agility, strength and aerobic conditioning. In addition, other investigators noted that improved compliance with injury prevention training programs would most likely occur if the programs target performance enhancement and neuromuscular retraining (Kelly A. 2008). Therefore, to increase player compliance and participation, they developed sports specific programs for competitive female high school players involved in basketball, soccer, lacrosse, volleyball, and tennis. These training programs included the essential Sports metrics neuromuscular retraining principles previously proven to decrease the rate of noncontact injuries in female athletes, along with other sports specific exercises and drills. All the athletes who participated were enrolled in prospective

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studies in which neuromuscular and performance indices were measured before and upon completion of the training program.

Another study was undertaken to determine if a sports-specific training program could improve neuromuscular and performance indices in female high school basketball players. A program was devised, which used the dynamic warm-up, jump training, strength training, and flexibility components from a previously published ACL injury prevention program (Barber-Westin S. and Noyes F., 2009.), along with new exercises and drills to improve speed, agility, overall strength, and aerobic conditioning. A battery of tests was conducted to determine the effectiveness of this training program in improving lower limb alignment on a drop-jump test, estimated V_ O2max, vertical jump height, and sprinting speed. Improved lower limb alignment while landing on a drop-jump test is believed by others to decrease the risk of occurrence of a noncontact ACL injury (24), although V_ O2max, vertical jump height, and sprinting speed are essential components of this sport.

In the video drop-jump test, statistically significant increases were found between pretrained and post trained test sessions on landing in the mean absolute knee separation distance (p, 0.0001), the mean normalized knee separation distance (p, 0.0001), and in the distribution of the subjects in the normalized knee separation distance categories (p, 0.0001). Improvement in the normalized knee separation distance was demonstrated in 91% of the subjects. A statistically significant improvement was found in the mean estimated V_ O2max score (p, 0.0001) and in the difference in the distribution of the subjects in the categories between pretrained and post train test sessions (p, 0.0001). Eighty-nine percent of the subjects improved this score. A significant improvement was found in the vertical jump test (p, 0.0001), as 70% of the subjects increased their scores. However, the effect size was small (0.09). There was no significant improvement in the 18-m sprint test. No subject sustained an injury that resulted in loss of time training or that required formal medical attention. All the subjects attended at least 14 of the 18 training sessions. (NOYES R.F., BARBER-WESTIN D., et. al., 2012)

Other study was to determine if female high school basketball show neuromuscular differences during landing and cutting tasks and to examine neuromuscular differences between tasks and between dominant and nondominant sides. Their purpose was to compare the lower extremity biomechanics of jumping and cutting in female basketball and soccer players. The general hypothesis was that female basketball and soccer players would demonstrate different neuromuscular control strategies when performing jumping and cutting tasks. The first specific hypothesis was that basketball players would have greater valgus knee moments, valgus knee angles, and vertical GRF than soccer players during a drop vertical jump (DVJ). Conversely, the second specific hypothesis was that soccer players would have increased valgus knee moments, valgus knee angles, and vertical GRF during the unanticipated cutting task. The third hypothesis was that side-to-side differences in knee valgus moments, knee valgus angles, and vertical GRF would exist in the groups of female athletes. Their subjects demonstrated differences in ground reaction forces and stance times during 2 movements associated with noncontact anterior cruciate ligament injuries. Knee valgus moment and angle were significantly influenced by the type of movement performed. Sport-specific neuromuscular training may be warranted, with basketball players focusing on jumping and landing and soccer players focusing on unanticipated cutting maneuvers. (Hanni R. Cowley., Kevin R. Ford., et. al. 2006).

Poor balance has been associated with increased injury risk among athletes. Neuromuscular-training programs have been advocated as a means of injury prevention, but little is known about the benefits of these programs on balance in high school athletes. To determine whether there are balance gains after participation in a neuromuscular-training program in high school athletes, in this study 62 female high school basketball players recruited from the local high school community and assigned to a training (n = 37) or control (n = 25) group. Training-group subjects participated in a 6-wk neuromuscular-training program that included plyo-metric, functional-strengthening, balance, and stability-ball exercises. The authors found a significant decrease in total BESS errors in the trained group at the posttest compared with their pretest and the control group ($P = .003$). Trained subjects also scored significantly fewer BESS errors on the single-foam and tandem-foam conditions at the posttest than the control group and demonstrated improvements on the single-foam compared with their pretest ($P = .033$). The authors found improvements in reach in the lateral, anteromedial, medial, and posterior directions in the trained group at the posttest compared with the control group ($P < .05$) using the SEBT. The study demonstrates that a neuromuscular-training program can increase the balance and proprioceptive capabilities of female high school basketball players and that clinical balance measures are sensitive to detect these differences. (Tamara C., McLeod V., et. al., 2009)

A similar study in female handball team, 35 players from 2 teams in the elite division participated. They had played handball for 14.9 (±3.2) years, 4.7 (±2.8) years at the top level. The total number of training hours per week was 10 to 11. There was a significant improvement in dynamic balance between test. The effect on dynamic balance was maintained 1 year after training. For static balance, no statistically significant changes were found. For the other variables measured, there were no statistical differences during the study period. In the Conclusion the ACL injury

prevention training program improved dynamic balance in an elite team handball player. (Holm, Inger P., et.al. 2004)

Another study examined the effects of 24 weeks of morning vs. evening same-session combined strength and endurance training on neuromuscular and endurance performance. Fifty-one men were assigned to the morning or evening training group, where S preceded E or vice versa or to the control group. Isometric force, voluntary activation, EMG and peak wattage during the maximal cycling test were measured. Training time did not significantly affect the adaptations. In the morning, no order specific gains were observed in neuromuscular performance. In the evening, the changes in isometric force and EMG were larger and in voluntary activation larger compared to controls. Peak wattage increased in the morning. Their current training program led to greater neuromuscular adaptations when SE-training was performed in the evening, whereas the ES-training provided more optimal conditions for endurance performance adaptations both in the morning and evening. (Küüsmaa-Schildt M., Eklund D., Newton R.N., et. al. 2017)

Participants included 28 healthy young women. Blood samples were collected to determine plasma levels of estradiol and progesterone immediately before the performance of the task: drop landing on a single leg from a 30-cm platform. Using ultrasonography, the distance between the tibia and the distal end of the fibula, regarded as the width of the tibiofibular syndesmosis, was measured in an upright position without flexion of the ankle. The peak ground-reaction force (GRF) on landing was measured using a force platform. The time to peak was measured as the time from initial ground contact to the peak GRF. Hip, knee, and ankle joint angles during the single-leg landing were calculated using a 3-dimensional motion analysis system. Muscle activities of the lower extremities were measured using surface electromyography. Their results were the width of the tibiofibular syndesmosis was significantly greater in the luteal phase when compared with the menstrual, follicular, and ovulation phases. Also, during the luteal phase, the Tp-GRF was significantly shorter than in the follicular phase hip internal rotation and knee valgus were significantly greater than in the menstrual phase knee flexion was significantly less than in the menstrual and follicular phases ankle dorsiflexion was significantly less than in the follicular phase ankle adduction and eversion were significantly greater than in the menstrual and follicular phases; and activation of the gluteus maximus before landing was significantly lower than in the menstrual and follicular phases. The luteal phase appears to be associated with decreased strength and laxity of the ankle as well as lower extremity muscle activity in women. The changes presumably represent a greater risk for sports injuries. (Okazaki M., Masaaki Kaneko M., et. al., 2017)

Objectives

The main aim of this study was to identify whether three neuromuscular coefficients as offered by the MGM-15 Jump Carpet relate to the average power output during jumping for female basketball players.

Subjects

The participants in this study were female basketball players (N = 20), aged from 9 to 11 years old that underwent a test using the MGM-15 carpet. The subjects participated in the ongoing national basketball league.

All the subjects were briefed beforehand regarding what the experiment consisted of and what they were required to do. The subjects were assured that any personal information would not be made public and their personal data recorded will be analysed under the cover of anonymity. Moreover, the subjects were instructed how to control social and routine aspects of their lives so that those variables would not interfere with the experiment's results. Also, after the briefing, the subjects were asked to confirm their understanding of what was required on a premade consent form.

Methods and Materials

We used the MGM-15 Jumping Carpet for test. The test consists of 15 jumps repeated 3 times: once for the left leg, once for the right one and last time on both legs. The legs must not be bent during the execution of the jumps. The software from the MGM-15 Jumping Carpet offered out, among others, four factors for each subject: average unit power (Avg_UP), structural variance coefficient (SVC), energetic variance coefficient (EVC) and force to speed asymmetry (FS_Asym). The Avg_UP is measured in watts, while the other coefficients are just a quantifiable number. The test was repeated 3 times and the average value for the two variables was recorded.

The Avg_UP is the average power developed by the subject during the jumping test.

The EVC is a coefficient that reflects the neuromuscular ability of the subject to control the technique of a movement at high speeds of repetition.

The SVC is also a neuromuscular coefficient that shows the ability of the subject to prepare for contact with a hard surface, an object or another person.

The FS_Asym reflects the difference between the ability of the subject to engage force and speed during a movement.

The protocol for the test was:

- 5 minutes explaining the test;
- 5-7 minutes' warm-up for the legs for the jumping test
- 2 minutes' preparation and getting used to the instrument;
- Calibration of the device;
- Measurement of the first set of 15 jumps on the both feet;
- 2 minutes' rest;
- Measurement of the first set of 15 jumps on the left foot;
- 2 minutes' rest;
- Measurement of the first set of 15 jumps on the right foot;
- 2 minutes' rest;
- If not valid, pause 10-15 minutes, repeat.

Results

Table 1. Correlations

		Avg_UP	CVE	CVS	FS_Asym
Avg_UP	Pearson Correlation	1	-.362	-.358	-.430
	Sig. (2-tailed)		.107	.111	.05
	N	21	21	21	21
EVC	Pearson Correlation	-.362	1	,552**	-.128
	Sig. (2-tailed)	.107		.010	.582
	N	21	21	21	21
SVC	Pearson Correlation	-.358	,552**	1	-.035
	Sig. (2-tailed)	.111	.010		.879
	N	21	21	21	21
FS_Asym	Pearson Correlation	-.430	-.128	-.035	1
	Sig. (2-tailed)	.051	.582	.879	
	N	21	21	21	21

Table 2. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,625[a]	.390	.283	.25191

Table 3. ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.691	3	.230	3.629	,034[a]
	Residual	1.079	17	.063		
	Total	1.770	20			

Table 4. Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.590	.137		11.607	.000
	EVC	-.022	.016	-.310	-1.353	.194
	SVC	-.016	.018	-.204	-.897	.382
	FS_Asym	-.668	.267	-.477	-2.497	.023

A linear regression statistical test was conducted to identify the relation between the jumping power output and the three other coefficients: EVC, SVC and force-speed asymmetry.

The correlation test showed that the average power output correlates with the force-speed asymmetry. Even though this is not a strong correlation it is still present. The sample size might be a reason for this low correlation.

The other two coefficients did not correlate with the average power out but they did correlate with each other. Due to this we will focus on the impact of force-speed asymmetry over the average power output.

One-point increase in the value of force-speed asymmetry corresponds to a 0.67 decrease in the average power output. Strength of the FS_Asym is almost 2 parts, even though we do not know what coefficients are responsible for the other parts.

The proportion of the three variables measured towards the average power output is 0.625 with a proportional increase of 0.390.

Conclusion

Both the structural and energetic coefficients refer to the same aspect of the neuromuscular process and therefore it was natural to identify a correlation.

The linear regression result between the power output and the force-speed asymmetry can indicate that there is an impact over the rate of variance of the asymmetry with regards to the power output. The negative value of the implication of force-speed asymmetry over the power output means that a higher power output relates to a lower force-speed asymmetry.

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Isometric Muscle Control Effect Over Movement Velocity During a Postural Balance Test

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Abstract

Background. Motor function is a neuromuscular process with high importance in human physical activity. Balance, power strength and movement speed are vital aspects of motor function that can improve physical performance. **Objective**. Our main objective was to identify the influence of isometric muscle exercise over the movement velocity during a balance test. **Subjects and Methods**. A number of 210 students from the Faculty of Physical Education and Sport, Babeş-Bolyai University, Cluj-Napoca participated in this study. We've used the AMTI Netforce for the balance test and half-squat 20 seconds for isometric exercise. **Results**. There was a significant statistical correlation between the displacement of center of pressure (COP) between the initial and final measurement. There was a significant statistical difference between the displacement of COP before and after the isometric exercise. There was no statistical difference regarding the velocity of COP before and after isometric exercise. **Conclusion**. Muscle fatigue due to isometric exercise in the half-squat stance does influence the displacement of COP but not the velocity of the COP, therefore it doesn't correlate with the body movement during a balance stance.

Keywords: balance, velocity of COP, displacement COP, isometric, muscle

Nomenclature

COP	- centre of pressure
Velocity_Ini	- value for the velocity of COP before the isometric exercises
Velocity_Final	- value for the velocity of COP after the isometric exercises
Avg_Displ_Ini	- average value for the displacement of COP before the isometric exercises
Avg_Displ_Final	- average value for the displacement of COP after the isometric exercises

Introduction

Development of motor fitness is particularly essential in professional sport, since its individual aspects or their combinations determine the skill level of athletes. Measuring motor fitness can be useful for strength, speed, and endurance sports. Different situations are observed in sports where motor coordination is more important, such as combat sports, where technical and tactical actions are often performed by athletes under conditions of extreme fatigue (creating disturbances in homeostasis). The fatigue accumulates over subsequent bouts and through incomplete recovery of energy substrates after several bouts (Stanisław et al., 2016).

Balance training is an interesting and controversial method of training for coaches because of the transversal effect that it may have on athletic performance in various sports and at different ages. From the literature, an evidence-based relationship between balance ability and the risk of injury is clear. In fact, studies have demonstrated that systematic training in a balance training program would be effective in reducing the risk of injurie. (Hubscher M, et.al.,2010)

Balance can be defined as the ability to maintain the body's center of gravity over the base of support and results from neuromuscular actions in response to continuous visual, vestibular and somato-sensory feedback. In recent years, balance training has become a very popular addition to more standard athletic training programmed in many sports. Basketball, for example, requires the players to habitually address physical contact and various situations involving balance instability, such as basketball-specific accelerations and decelerations, changes in direction, penetrations into the defensive perimeter, boxing out, dribbling and defense position recovery. (Boccolini G. et.al., 2013)

Muscle strength should be distinguished from muscle power; muscle strength is defined as the force or tension that the muscle can exert against a resistance, while muscle power is defined as the speed of movement or the rate at which

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a resistance can be moved per unit of time. (Kazuhiro Kawanabe, et.al., 2007)

A study showed that players who participated in balance training for 12 weeks, compared to players who trained with isotonic machines, exhibited a significantly increase in balance and muscular power as measured through a vertical jump. In conclusion, balance training using unstable boards was an effective training method for improving balance and the vertical jump, which is a basketball-specific action that frequently occurs in this sport. (Oliver GD., Di Brezzo R., 2009).

Throwing accuracy and throwing speed were measured using Functional Throwing Performance Index (FTPI) and radar gun respectively, at zero, 12, 24 and 30 weeks in accordance with the A-B-A single-subject design. The neuromuscular training of the throwing arm was performed for 12 weeks, two days a week of supervised training including rhythmic stabilization drills were performed. A non-supervised training session including shoulder strengthening programme was conducted three days a week.

Participants demonstrated significant improvement in throwing accuracy ($p < 0.001$) and speed ($p < 0.001$) after 12 weeks of neuromuscular training. Six weeks' post-withdrawal of the neuromuscular training on throwing accuracy was not significant ($p ¼ 0.117$), However, speed was sustained ($p ¼ 0.013$). Neuromuscular training showed an improved efficiency in throwing performance following 12 weeks of training. The sustained effect was not observed following 6 weeks of withdrawal of training. (Hydar S.A., et.al., 2018)

In sport where throws in standing positions are allowed its necessitates that the motor fitness of athletes be tested under conditions of extreme fatigue. The grip is used to transfer forces caused by actions performed during attack or defense to an opponent's body. The specific technical and tactical actions cause the athlete to adapt individual. After repetition of movements with varied external resistance, the individual differentiation of an athlete's special motor preparation is achieved. (Sogabe A., et. al.2008)

Techniques can be performed while standing on both legs or on one leg. Several studies in sport have examined the importance of balance using a variety of research models and paradigms. Comparative research strategies are typical in the literature. Analysis of age categories found the best results in static balance in adult athletes, followed by juniors and cadets. (Sterkowicz S, et.al.2012). In another study, balance among national and international competitive-level athletes was similar to those at the regional competitive level (Paillard T, et.al 2002). Postural balance of elite athletes was superior to controls (Perrin P, et.al.2002). Balance examinations have been performed under various conditions, eyes open, eyes closed (Hrysomallis C 2011), and the results have been compared to those of untrained subjects. (Perrin P, et.al 2002).

The majority of previous studies have been conducted to analyze the effect of muscle strength on static and dynamic balance performance in populations with significant muscle weakness. These studies have utilized elderly (Carter et al., 2002), post stroke (Kligyt et al., 2003), and osteoporosis (Lord et al., 2002) subjects to determine the relationship between strength and balance but results have varied. These inconsistent findings may be a result of variations in research design including the measurement of strength and balance with different methods of assessment.

Objectives

This study aimed to identify whether or not isometric exercises influence the velocity of the COP.

As a secondary objective, we wanted to analyse whether or not the final position of COP changes after isometric exercises.

Subjects

In this study 210 subjects were involved from beginning to end. They were students from the 1st year of studies from the Faculty of Physical Education and Sport, Babes-Bolyai University in Cluj-Napoca. They were between 19 and 21 years of age and out of them there were 57 females and 153 males.

All the subjects were briefed beforehand regarding what the experiment consisted of and what they were required to do. The subjects were assured that any personal information would not be made public and their personal data recorded will be analysed under the cover of anonymity. Moreover, the subjects were instructed how to control social and routine aspects of their lives so that those variables would not interfere with the experiment's results. Also, after the briefing, the subjects were asked to confirm their understanding of what was required on a premade consent form.

Methods and Materials

Our study consisted of two main parts: the initial test and the final test. Both tests consisted of balance tests. The final test had, besides the balance test, isometric exercises that were done before each measurement.

The balance test was done using the AMTI NETforce platform BP400600. It is a force platform that measures the pressure force of the subject. Because of this it has the ability to register any variations or modifications regarding the

centre of pressure (COP), and, at its core, the movement of body's centre of gravity. After the test, the platform's software allows us to visualize two parameters, among others: velocity and displacement of the COP.

Displacement is the straight-line distance from the starting position to the final one at the end of the test. Not to be confused with the trajectory.

Velocity is an average speed of movement for the COP during the test.

The isometric effort consisted of three exercises: one for the upper body, one for the core and one for lower body. For the first one the subject was required to hold a half push-up stance for 20 seconds, for the second one a 30 second plank and for the final one a 30 second half-squat.

We measured, for each of the two balance tests, one postural stance: the standing position – feet shoulder width apart, body straight, arms to the sides of the body and the head straight.

The protocol for the two tests was:

- 3 - 5 minutes explaining the test;
- 2 minutes' preparation and getting used to the instrument;
- Calibration of the device;
- Measurement of the standing position;
- Pause 10-15 seconds, and if not valid, repeat.

For the statistical analysis of the data we've used the SPSS v17.0 version of the software. A paired sample t-test was conducted for each balance parameter between the initial and final measurements.

Results

Tabel 1. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Avg_Displ_Ini	.7145	210	.35642	.02460
	Avg_Displ_Final	.7985	210	.38775	.02676
Pair 2	Velocity_Ini	3.5214	210	3.70768	.25585
	Velocity_Final	4.0250	210	1.33117	.09186

Tabel 2. Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Avg_Displ_Ini & Avg_Displ_Final	210	.000	.997
Pair 2	Velocity_Ini & Velocity_Final	210	.038	.588

Tabel 3. Paired Samples Test

		t	df	Sig. (2-tailed)
Pair 1	Avg_Displ_Ini - Avg_Displ_Final	-2.310	209	.022
Pair 2	Velocity_Ini - Velocity_Final	-1.875	209	.062

A paired-sampled t-test was conducted to compare the value of the initial average displacement before isometric exercises (Avg_Displ_Ini) and the value of the final average displacement after the isometric exercises (Avg_Displ_Final) for the subjects. There was a significant difference in the scores of the initial test (M= 0.71451, SD= 0.356418) and of the final test (M= 0.79849, SD= 0.387749) conditions; t(209)= -2.31, p = 0.022. These results suggest that the isometric effort the subjects undergone did affect the displacement of COP during the standing stance.

A paired-sampled t-test was conducted to compare the value of the initial velocity before the isometric exercises (Velocity_Ini) and the value of the final velocity after the isometric exercises (Velocity_Final) for the subjects. There was no significant difference in the scores of the initial test (M= 3.52136, SD= 3.707682) and of the final test (M= 4.02504, SD= 1.331167) conditions; t(209)= -1.875, p = 0.062. These results suggest that the isometric effort the subjects undergone did not affect the velocity of COP during the standing stance thought the values are close to a significant level.

Conclusion

The study of balance stances and their impact over physical activity should be conducted often to identify the level of influence balance has over physical fitness development. A poor balance may lead to faulty execution of a movement and thus it may affect its result.

Our study concluded that there was a significant difference between the displacement values of COP before and after the isometric effort. This means that the exercises the subjects did impacted the final position of COP at the end of the test. The fact that isometric effort influences the final position of COP means that, after such exercises, the subject can't control the place where his body ends the movement. This may indicate that there will be a translation of the postural vertical line over the course of the technique that may have negative effect on its efficiency.

There were no other significant differences between the initial and final values of the velocity of COP. Even though the statistical result was close to being significant our conclusion is that isometric exercises do not influence the speed of movement for COP. We do suggest that a larger sample should be used for further studies and a more detailed analysis of the measurement protocol should be conducted to focus on evaluating the velocity aspect of balance.

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