

Optimization of basic movement skills for early-age gymnasts based on augmented reality

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ABSTRACT

The increasing use of gadgets among young children has reduced physical activity levels, negatively affecting motor development and the acquisition of fundamental movement skills needed in artistic gymnastics. Since early childhood is a critical period for motor skill development, a lack of active movement may hinder children's ability to perform basic gymnastics techniques. Although technology is widely used by children, there is still limited learning media that combines digital technology with physical activity to encourage movement and skill development. This study aimed to develop an Augmented Reality-based Flash Card (FCAR) product to improve the basic movement skills of early-age gymnasts. The FCAR displays three-dimensional projections of motor movements through augmented reality technology, allowing children to observe and imitate the movements in an interactive and enjoyable way. By integrating learning and play, the product encourages children to be physically active while practicing fundamental gymnastics skills. The study employed the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model as a Research and Development framework. The product was designed, developed, implemented, and evaluated through a systematic process involving expert validation. The results indicated that the FCAR achieved an overall expert assessment score of 85.41%, categorized as "good." Gymnastics and information technology experts confirmed that the product meets the movement composition standards outlined in the Code of Points for Artistic Gymnastics and is suitable for use by early-age gymnasts. Therefore, FCAR can be considered an innovative and effective learning medium for supporting motor skill development in children.

Keywords: artistic; motor; augmented reality; flash card; early age



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INTRODUCTION

The development of sports science and technology presents new opportunities in fulfilling the motor learning process for early childhood. On the other hand, the influence of technology such as gadgets is inevitable and has a negative impact on children who become physically inactive, which in turn adversely affects their motor development (Abbas, 2020)

Physical inactivity in early childhood has become a primary concern for parents. Evidence shows that a link exists between children's activity levels and their health status. A lack of appropriate physical activity during childhood can lead to failure in developing basic movement skills during the preschool and primary school years, consequently causing failure in acquiring specific motor skills. Conversely, mastery of these skills is a prerequisite for successful introduction to sports activities, including gymnastics. However, with proper parental guidance, technology can also have a positive influence that motivates students to move through *augmented reality* applications designed to meet the needs of gymnastics (Aji-Putra et al., 2020)

Augmented Reality is a technology capable of integrating the real world with virtual or digital elements such as images, sounds, or 3D objects displayed in real time on a *smartphone* (Putra et al., 2020). The *Augmented Reality* presented on a smartphone contains features with images of various children's motor movements consisting of locomotor, non-locomotor, and manipulative movements that children must practice. To stimulate children's motivation to follow movements in the flash card game, each card is projected with Augmented Reality. This Augmented Reality-based flash card hereinafter referred to as FCAR is a combination of three technological developments: flash card creation, Augmented Reality technology, and smartphones, developed to improve the basic movement skills of early-age gymnasts (Putra et al., 2019a).

Based on the problems described above, the researchers propose how the development of an augmented reality-based flash card can optimize the basic movement skills of early-age gymnasts (Putra et al., 2019b).

Research in augmented reality-based learning media has demonstrated its potential to increase engagement and motivation in physical education settings. In the context of artistic gymnastics, which demands mastery of precise technical movements from an early age, AR-based tools offer a promising medium through which early-age gymnasts can visualize and practice complex motor patterns interactively (Aji-Putra et al., 2020; Putra et al., 2020). The development of the FCAR product responds to this gap by combining flashcard pedagogy with AR technology to deliver a structured, game-like training medium aligned with the composition requirement code of points for artistic gymnastics.

METHOD

This study employs a Research and Development (R&D) method (Glynn et al., 2022). Research and development is a research method used to produce a specific product such as a design, model, prototype, or learning media, and to test the effectiveness of that product (Hernández-Beltrán et al., 2023). This research model uses the ADDIE development model (Ihsan, 2015). The ADDIE model consists of 5 stages: Analysis, Design, Development, Implementation, and Evaluation. All five stages of the ADDIE model require a systematic and systemic approach; the first year covers the Analysis, Design, and Development steps, while the second year covers the Implementation and Evaluation steps. This study reports on the first year of the research (Analysis, Design, and Development stages) as the basis for product development and initial expert validation (Glynn et al., 2022).

The Optimization of Basic Movement Skills for Early-Age Gymnasts Based on Augmented Reality to Meet the Composition Requirement Code of Points for Artistic Gymnastics was conducted at Persani Semarang City. Field trials were conducted in the gymnastics sport discipline of artistic gymnastics with a representative sample of early-age gymnasts in Semarang City. Product trials were conducted to obtain data on the Augmented Reality product for basic movement skills in artistic gymnastics, encompassing forward roll, tiger jump, backward roll, handstand, cartwheel, round off,

handspring, and head kipas a basis for providing an alternative source of augmented reality-based gymnastics basic movement training media for early-age gymnasts to meet the composition requirement code of points for artistic gymnastics. The trial subjects in this study were the same 14 artistic gymnastics athletes and 2 coaches from the Wimilia Gymnastics Club in Semarang City who participated in both the initial needs analysis observations and the product validation stage.

The instruments used to collect data in this study were questionnaires and field observations. Questionnaires were used to obtain systematic and targeted information, developed from expert evaluation results using a Likert scale of 1-4 to gather data from male artistic athletes, female artistic athletes, and coaches. The questionnaire items covered aspects of originality, innovation superiority, usefulness, safety, completeness of supporting data, and cognitive substance of artistic gymnastics basic movements.

The research procedure adopting the ADDIE model approach can be seen in Figure 1 below:

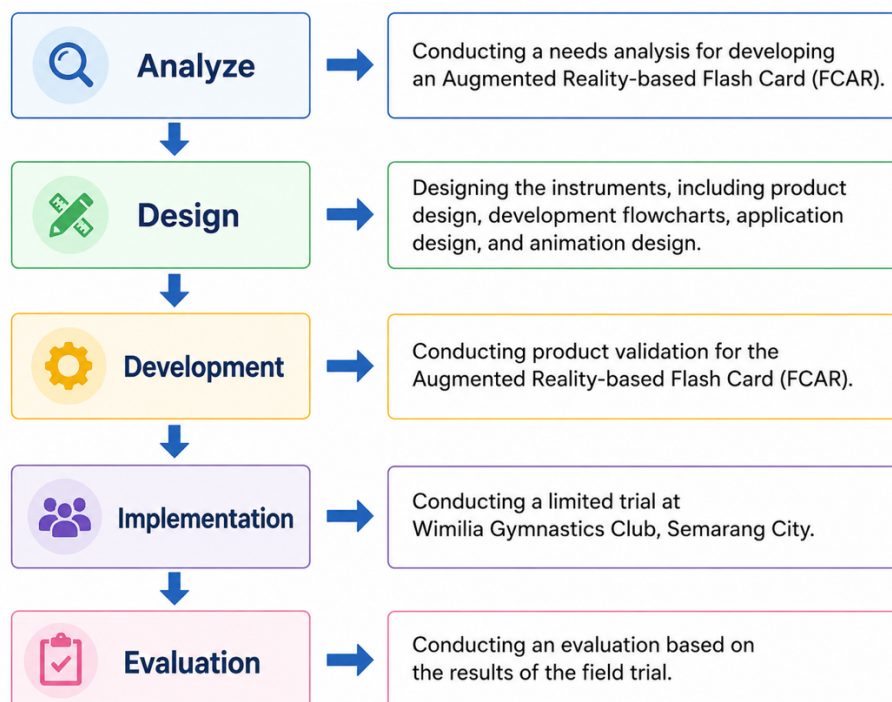


Figure 1. Research Flowchart

RESULTS

This study produced a smart card product based on *Augmented Reality (AR)* developed using the *Research and Development* model. The research was conducted in three stages: *Analysis*, *Design*, and *Development*. The results of developing the *Augmented Reality (AR)*-based smart card product are described in detail according to the *Research and Development* method (Iswanto et al., 2023; Jakse et al., 2019) as follows:

Analysis

At this stage, the analysis was conducted regarding problems occurring in early childhood. The researchers conducted observations at the Wimilia Gymnastics Club in Semarang City, involving 14 gymnasts and 2 coaches, using two methods: interviews and tests. Interviews were conducted by asking about the children's training habits and activities at home, and their interest in gadgets. It was found that most children were already accustomed to using *smartphones* daily. Observational tests were conducted to assess artistic gymnastics basic movement skills, including forward roll, tiger

jump, backward roll, handstand, cartwheel, round off, handspring, and head kip. Based on motor ability tests and observations consisting of a 10x4m *shuttle run* in which the average student scored 14 or below, a throwing and catching test with an average of 1 catch (very poor), a *stork stand positional balance* test with a result of 9.54 (very poor), and a 30m sprint test with a result of 9.6 (very poor).

The preliminary analysis indicated that children were already familiar with smartphones but their motor development remained below average. Therefore, developing an Augmented Reality (AR)-based smart card aims to improve the motor skills of early-age children.

Design

The product design was structured according to the learning needs and achievement of objectives, namely developing an application called *SCAR Kids (Smart Card Augmented Reality for Kids)*. This application is used in conjunction with a smart card containing a barcode to be scanned using the SCAR Kids app, which then displays an animation guiding children to perform motor movements. The initial steps involved designing the application, its menus and content, followed by designing attractive animations, and finally designing the smart card as the marker. The initial application design can be seen in the following figures.

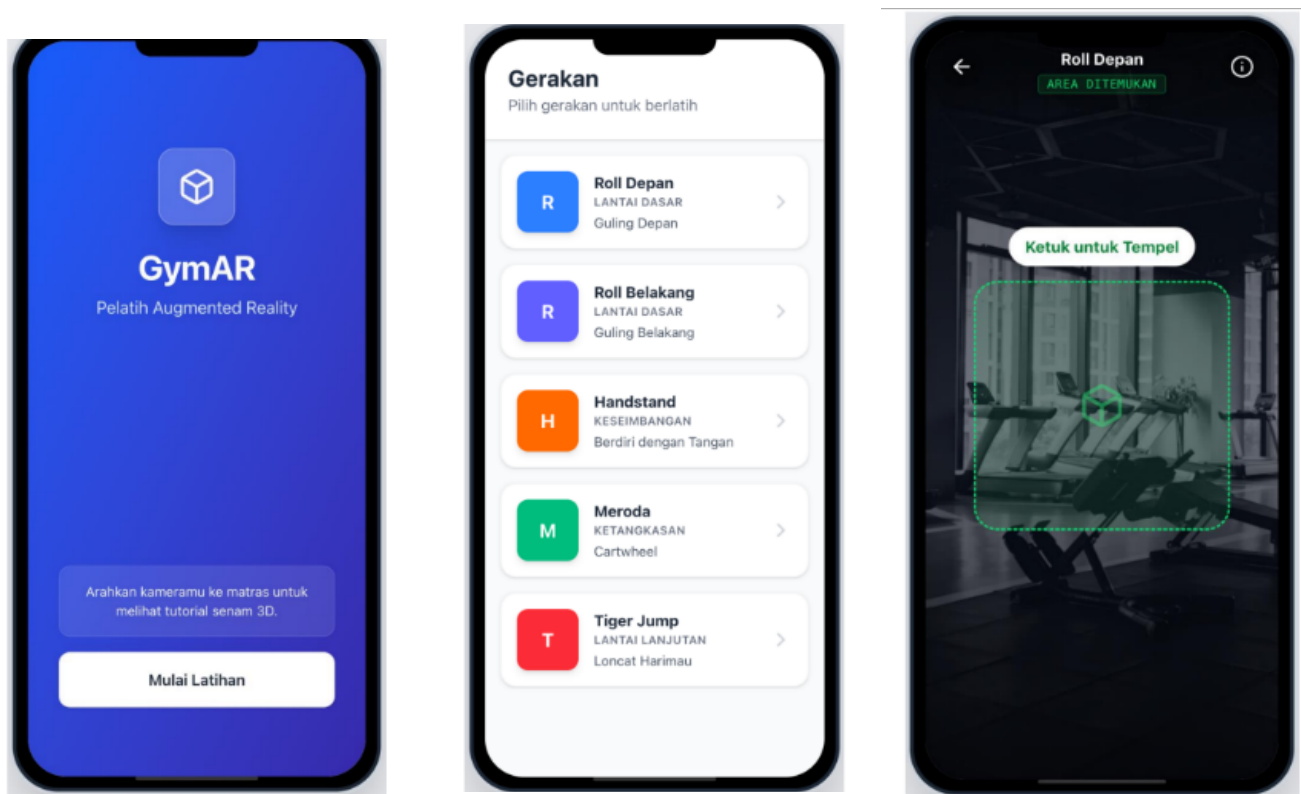


Figure 2. Application Display Layout

This image depicts an Augmented Reality-based gymnastics learning app that aims to help users understand movement techniques such as front roll, handstand, and meroda with 3D visualizations displayed directly in the real environment through a smartphone camera. This

technology can make the learning process more interactive, interesting, and easy to understand than just looking at ordinary pictures or videos.

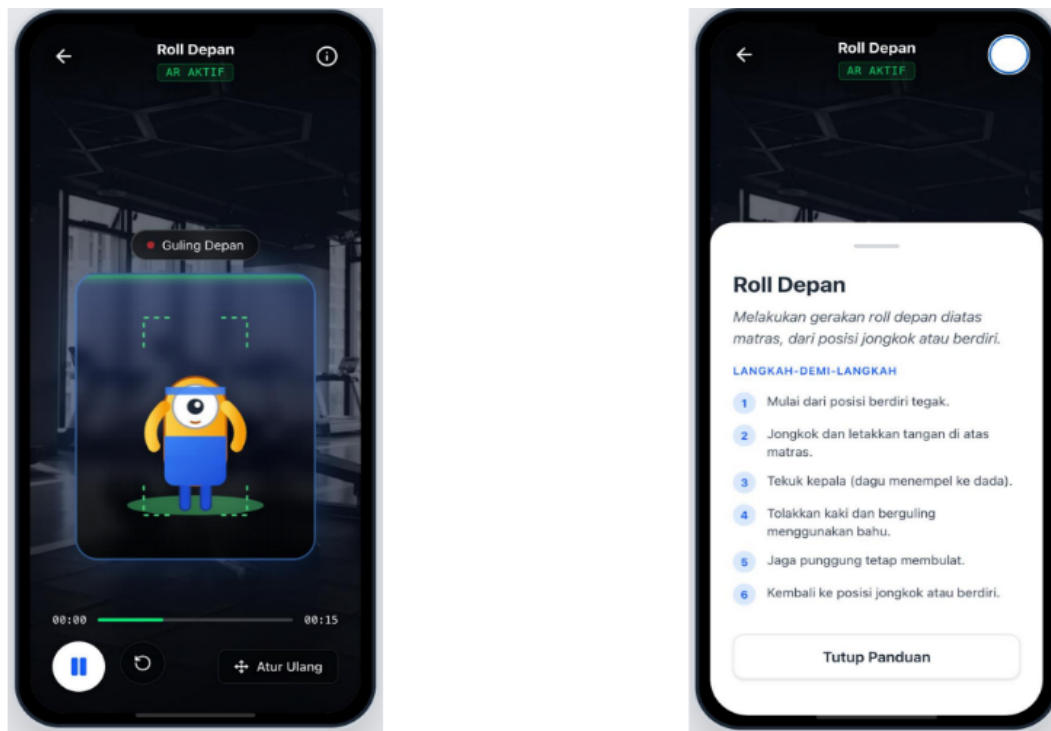


Figure 3. Description of Each Menu in the Application

Expert validation of the augmented reality-based product to meet the composition requirement code of points for artistic gymnastics was conducted through content validity by requesting assessments from competent individuals, namely experts and specialists (Ihsan, 2015). The results of the questionnaire completed by gymnastics and technical experts are presented below:

Table 1. Questionnaire Results from Gymnastics and Information Technology Experts

NO	Criteria	Assessment Indicator	Expert Assessment Result			
			1	2	3	4
1	Originality	Represents the researcher's own findings.	3	3	4	3
		Contains distinguishing aspects compared to existing sports technology.	3	3	4	3
2	Innovation Superiority	Has advantages in innovative design layout.	4	3	4	3
3	Usefulness	Has an application that functions to identify basic movement skills of early-age gymnasts.	4	4	3	4
4	Safety	Has a good level of safety for artistic gymnasts.	4	3	3	4
5	Completeness of Supporting Data	Has various features for using the augmented reality application for basic movements of early-age gymnasts.	3	3	3	4
6	Cognitive Substance of Artistic Gymnastics Basic Movements	Comprehension of movement concepts covering the preparatory, execution, and final positions of basic movement skills: forward roll, tiger jump, backward roll, handstand, cartwheel, round off, handspring, and head kip for early-age gymnasts.	4	3	3	3

Source: Research Results 2025.

Table 2. Percentage Assessment of Gymnastics and Technical Experts

NO	Criteria	Assessment Indicator	Percentage
1	Originality	Represents the researcher's own findings.	81.25 %
		Contains distinguishing aspects compared to existing sports technology.	81.25 %
2	Innovation Superiority	Has advantages in innovative design layout.	87.5 %
3	Usefulness	Has an application that functions to identify basic movement skills of early-age gymnasts.	93.75 %
4	Safety	Has a good level of safety for artistic gymnasts.	87.5 %
5	Completeness of Supporting Data	Has various features for using the augmented reality application for basic movements of early-age gymnasts.	81.25 %
6	Cognitive Substance of Artistic Gymnastics Basic Movements	Comprehension of movement concepts covering the preparatory, execution, and final positions of forward roll, tiger jump, backward roll, handstand, cartwheel, round off, handspring, and head kip for early-age gymnasts.	81.25 %

Source: Research Results 2025.

The overall average assessment by gymnastics and technical experts across all items in the measurement instrument covering 6 aspects and 7 statement items yielded an average percentage of 85.41%. This percentage result falls within the 'good' assessment category. It can therefore be concluded that the augmented reality-based product for optimizing basic movement skills of early-age gymnasts to meet the composition requirement code of points for artistic gymnastics is applicable for early-age use.

DISCUSSION

The gross motor developmental needs of junior artistic gymnasts are critically important to ensure optimal physical development. Gross motor skills involve the ability to move large muscle groups of the body, such as the leg, arm, and back muscles, which play a role in basic movements such as jumping, running, and maintaining balance (Opala-Berdzik et al., 2021). In artistic gymnastics, gross motor skills must be trained from an early age so that junior gymnasts can perform movements with good control and strength. This helps them master fundamental techniques such as jumps, somersaults, and rotations, which form the primary foundation in artistic gymnastics (Berisha, 2021; Russo et al., 2021).

In addition, gross motor training in junior gymnasts also supports body coordination and balance, which are important aspects of this sport. Artistic gymnastics requires the ability to control the entire body when performing complex movements on gymnastics apparatus such as the balance beam or parallel bars. Structured gross motor training will help gymnasts develop body awareness and the ability to maintain balance, which are essential for avoiding injury and achieving optimal performance (Palmer et al., 2019).

Good gross motor development in junior artistic gymnasts also provides a foundation for the development of advanced physical skills. With regular and appropriate training, gymnasts can improve muscle strength, physical endurance, and flexibility. These needs not only help them perform better in competition, but also provide a good physical health foundation for the future (Russo et al., 2021). It is therefore important for coaches and parents to support the gross motor development of

gymnasts from an early age through training appropriate to the child's developmental age and physical capacity.

The findings of this study add further practical and scientific contributions to understanding the development of basic movement skills forward roll, tiger jump, backward roll, handstand, cartwheel, round off, handspring, and head kipin early-age gymnasts. Overall, understanding the relationship between the use of *augmented reality*-based technology in the artistic gymnastics training process makes training for early-age gymnasts more engaging and enjoyable, while optimizing their basic movement skills to meet the *composition requirement code of points for artistic gymnastics*.

CONCLUSION

Expert validation of the Augmented Reality (AR)-based Flash Card (FCAR) product yielded an overall average assessment of 85.41%, categorized as 'good,' indicating that the product meets expert-assessed criteria of originality, innovation, usefulness, safety, completeness of supporting data, and cognitive substance of artistic gymnastics basic movements. The AR media was assessed as capable of presenting engaging, interactive, and comprehensible movement visualizations suitable for early-age gymnasts.

The use of AR is expected to help children understand movement concepts concretely and progressively, in accordance with the characteristics of early childhood motor development. Future research should proceed to the Implementation and Evaluation stages of the ADDIE model to empirically test the effectiveness of the AR-based FCAR product in improving actual motor skill outcomes among early-age gymnasts.

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest in this study.

REFERENCES

- Abbas, R. A. A. (2020). *Effective Mental Skills In The Reduction Forgetfulness By The Law Of Artistic Gymnastic For Female Students Of The Faculty Of Physical Education And Sports Science*. Cabidigitallibrary.Org. <https://doi.org/10.5555/20203211297>
- Aji-Putra, R. B., Rahayu, T., & Kasmini, W. (2020). *The Software Instrument For Gymnast Posture Analysis*. Rua.Ua.Es. https://Rua.Ua.Es/Dspace/Bitstream/10045/109949/6/Jhse_17-2_20.Pdf
- Berisha, M. (2021). A Biomechanical Examination Of The Inclusion Of Active Flexibility In Artistic Gymnastic Movements Requiring Mobility. In *Pedagogy Of Physical Culture And Sports* (Vol. 25, Issue 5, Pp. 267–274). Sergii Iermakov. <https://doi.org/10.15561/26649837.2021.0501>
- Cagran, C., Huber, P., & Müller, W. (2010). Dynamic Force Measurements For A High Bar Using 3d Motion Capturing. *Journal Of Biomechanics*. <https://www.sciencedirect.com/science/article/pii/S0021929009006095>
- Glynn, B., Laird, J., Herrington, L., Rushton, A., & ... (2022). Analysis Of Landing Performance And Ankle Injury In Elite British Artistic Gymnastics Using A Modified Drop Land Task: A Longitudinal Observational Study. In *Physical Therapy In Elsevier*.

<https://www.sciencedirect.com/science/article/pii/S1466853x22000177>

- Hernández-Beltrán, V., Espada, M. C., Muñoz-Jiménez, J., & ... (2023). Evolution Of Documents Related To Biomechanics Research In Gymnastics. In *Biomechanics*. Mdpi.Com. <https://www.mdpi.com/2673-7078/3/4/39>
- Hou, Y., Zhang, Y., Liu, Y., Yuan, H., & Lei, X. (2023). Mindfulness Profiles Among Chinese University Students: Exploring Differences In Phenomenon, Cognition, And Performance Of Mind Wandering. In *Mindfulness* (Vol. 14, Issue 4, Pp. 908–918). Springer Science And Business Media Llc. <https://doi.org/10.1007/s12671-023-02080-0>
- Ihsan, H. (2015). Validitas Isi Alat Ukur Penelitian: Konsep Dan Panduan Penilaiannya. *Pedagogia*. <https://ejournal.upi.edu/index.php/pedagogia/article/view/6004>
- Iswanto, A., Siswantoyo, S., Sutapa, P., Arga, M. W., Budiarti, R., & Susanto, S. (2023). Analysis Of Difficulties Learning Artistic Gymnastical Movements In Elementary Students. In *Fizjoterapia Polska* (Vol. 23, Issue 3, Pp. 198–202). Dj Studio Dariusz Jasinski. <https://doi.org/10.56984/8zg143z0j>
- Jakse, B., Sekulic, D., Jakse, B., Cuk, I., & Sajber, D. (2019). Bone Health Among Indoor Female Athletes And Associated Factors; A Cross-Sectional Study. In *Research In Sports Medicine* (Vol. 28, Issue 3, Pp. 314–323). Informa Uk Limited. <https://doi.org/10.1080/15438627.2019.1696344>
- Lemos, J. R., Cunha, F. A. Da, Lopes, A. J., & ... (2020). Respiratory Muscle Training In Non-Athletes And Athletes With Spinal Cord Injury: A Systematic Review Of The Effects On Pulmonary Function, Respiratory Muscle Strength *Journal Of Back And* <https://doi.org/10.3233/bmr-181452>
- Liang, C., & Liang, X. (2012). *Dynamic Mechanism Of Sports Cutting-Edge Technique Development And Innovation*. 34, 337–342. <https://doi.org/10.1016/j.proeng.2012.04.058>
- Opala-Berdzik, A., Głowacka, M., & Juras, G. (2021). Postural Sway In Young Female Artistic And Acrobatic Gymnasts According To Training Experience And Anthropometric Characteristics. In *Bmc Sports Science, Medicine* Springer. <https://doi.org/10.1186/s13102-021-00236-w>
- Palmer, K. K., Chinn, K. M., & Robinson, L. E. (2019). The Effect Of The Champ Intervention On Fundamental Motor Skills And Outdoor Physical Activity In Preschoolers. In *Journal Of Sport And Health Science*. Elsevier. <https://www.sciencedirect.com/science/article/pii/S2095254618301212>
- Pan, W., Turrin, M., Louter, C., Sariyildiz, S., & Sun, Y. (2019). Integrating Multi-Functional Space And Long-Span Structure In The Early Design Stage Of Indoor Sports Arenas By Using Parametric Modelling And Multi-Objective Optimization. *Journal Of Building Engineering*, 22(January), 464–485. <https://doi.org/10.1016/j.jobe.2019.01.006>
- Pentidis, N., Mersmann, F., Bohm, S., Giannakou, E., & ... (2020). Effects Of Long-Term Athletic Training On Muscle Morphology And Tendon Stiffness In Preadolescence: Association With Jump Performance. In *European Journal Of* Springer. <https://doi.org/10.1007/s00421-020-04490-7>
- Putra, R. B. A., Pramono, H., Nurharsono, T., & ... (2019). Image Analysis Of Ideal Antropometric Percentage Proportion Of Men Artistic Gymnastic Apparatus. ... *On Physical Education* <https://www.atlantispress.com/proceedings/acpes-19/125921431>
- Putra, R. B. A., Rahayu, T., & Kasmini, W. (2020). The Importance Of Paying Attention To Anthropometrics In The Selection Athletes. ... *Conference On Science* <https://www.atlantispress.com/proceedings/iset-19/125941423>
- Rajpoot, Y. S., Ghai, G. D., Bagchi, A., & ... (2012). Biomechanical Analysis Of Selected Holding

Positions On Parallel Bar In Gymnastic. In *International Journal Of Academia.Edu*.
https://www.academia.edu/download/79470819/15._Gymnastic.Pdf

Russo, L., Palermi, S., Dhahbi, W., Kalinski, S. D., & ... (2021). Selected Components Of Physical Fitness In Rhythmic And Artistic Youth Gymnast. In *Sport Sciences For Springer*.
<https://doi.org/10.1007/S11332-020-00713-8>

Simorgh, L., Mahdavia, E., & Arzani, P. (2024). The Comparison Of The Psoas Muscle Thickness And Strength, And Sagittal Lumbopelvic Alignment In Female Gymnasts With Sway-Back Posture And Normal In *Acta Gymnica*. Gymnica.Upol.Cz.