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FUTURE ISSUES IN WRESTLING RESEARCH - A SPORT SCIENCES PERSPECTIVE

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INTRODUCTION

As the most traditional combat sport in the Olympic Games, wrestling has an enormous visibility, especially due to the high number of medals at stake. Moreover, wrestling is part of continental competitions (e.g., Pan-American Games, European Games, Asian Games, African Games) and world championships for different age groups (United World Wrestling, 2021). High-level athletes development is long-term endeavor demanding specialized professionals to provide the best approach available. Thus, the cost of this process can be quite high, and those managing sport programmes need to decide where, how and when to direct the support. Therefore, countries try to optimize their limited resources to sports with higher appeal or strategically relevant to the sport policy. In this context, the scientific evidence has been cited as an important element in the process of long-term athlete development (Rees et al., 2016). Indeed, a study reported that the number of papers related to Olympic sports was positively correlated to the medal table in the Rio Olympic Games: Spearman $r = 0.84$ for the relationship between papers about Olympic sports and total number of medals, and Spearman $r = 0.70$ for the relationship between papers about Olympic sports and number of gold medals (Moreira and Franchini, 2017). Additionally, it was demonstrated that the sport sciences scientific production increased linearly in countries with cities hosting the summer Olympic Games and that this increment was more accentuated after the host city announcement compared to a period before this fact (Franchini and Kokubun, 2019).

Specific strategies have been used to optimize the interaction between coaches and sport scientists, including the creation of sports institutes such as the Australian Institute of Sport (Rees et al., 2016), L'Institut National du Sport, de l'Expertise et de la Performance in France (Millet et al., 2021), the USA Olympic Training Center in Colorado Springs, the Japanese Institute of Sports Sciences, the English Institute of Sport to name only a few, and the insertion of sport scientists in the multidisciplinary technical commission working directly with high-level athletes (Barlett and Drust, 2020). It is also important to verify what has been published about specific sports to better understand the information available, and to guarantee that cutting-edge knowledge is provided to coaches. In this context, a bibliometrics analysis of Olympic combat sports research (Franchini et al., 2018) indicated that investigations about these sports represent around 1% of all scientific information available in Sport Sciences, even though these sports represent around 20-25% of all medals disputed in the Olympic Games. Therefore, this is an area to be consolidated in terms of research. More recently, Millet et al. (2021) analyzed the publications related to Olympic sports in exercise and sport journals indexed in PubMed, and included wrestling in their investigation. They found 405 articles related to wrestling and considered 400 in their final analysis, reporting the five most cited articles: three investigating rapid weight loss (Oppliger et al., 1996; Steen and Brownell, 1990; Webster et al., 1990), one related with coping strategies of U.S. Olympic wrestlers (Gould et al., 1993), and one analyzing the physiological and performance responses to a simulated wrestling tournament (Kraemer et al., 2001). Although the predominance of the physiological aspects among these articles, the most cited one was related to sport psychology (i.e., coping) (Gould et al., 1993). Therefore, these three main topics seem to be the mainstream in wrestling research. Indeed, when reporting the main research topics in wrestling-related research, Millet et al. (2021) found the following order: physiology, injuries and medicine, training and testing, psychology, performance and biomechanics and equipment. Knowing what have been done is essential to find the gaps in wrestling research. Thus, the main goals of the present article is to provide an overview of sport sciences wrestling-related research, and to present topics that deserve information. While the first goal can be achieved via a more formal and objective way, the second is based on the experience of the author and should be taken with caution.

SPORT SCIENCES RESTLING-RELATED RESEARCH

Millet et al. (2021) analyzed the scientific publication in 116 sport/exercise journals on PubMed for both summer (40) and winter (10) Olympic sports and observed that team sports, specially American professional sports were those modalities with more articles published and cited. Therefore, it seems that social relevance of sports affect the scientific interest and it was suggested by these authors that sports with more economical impact may be the main reason for this. Although combat sports are practiced worldwide and represented around 26% of all medals disputed during the Tokyo 2020 Olympic Games, the scientific interest in these sports is not high. This is confirmed by the fact that only nearly 1% of the Sport Sciences research indexed in the Web of Science was related to Olympic combat sports (Franchini et al., 2018). Specifically regarding wrestling, no study analyzed the bibliometrics of scientific publications. This kind of information can be valuable to understand what has been investigated in this sport, whether this knowledge have been incorporated to training routines and what should be investigated to provide better decision-making concerning training procedures.

To identify the wrestling-related scientific research, a search was conducted in Web of Science in November 4th 2021, using the terms "wrestling" and "wrestler" in the Sport Sciences area. The results retrieved 1196 publications, from which 913 were original articles, and 59 were review articles. Therefore, these 972 articles were analyzed. Briefly, the main goal was to determine who investigated wrestling and what aspect was studied, which universities supported these studies, which countries have more tradition in this type of research, and where these articles were published, and when these investigations were published.

Table 1 presents the authors who published more than 10 articles related to wrestling in Sport Sciences area and a representative example of research conducted by each author.

Table 1: Researchers with more than 10 wrestling-related articles indexed in the Web of Science for the Sport Sciences area, and example of a representative study.*

Author	Number of articles published	Title of representative article published
Housh TJ	23	Midwest wrestling study - prediction of minimal weight for high-school wrestlers
Johnson GO	23	Allometric scaling of isokinetic peak torque: the Nebraska Wrestling Study
Comstock RD	19	Epidemiology of concussions among United States high school athletes in 20 sports
House DJ	17	Estimation of body density in young wrestlers
Utter AC	16	NCAA rule change improves weight loss among national championship wrestlers
Horswill CA	12	Weight loss in wrestlers
Kerr ZY	12	Epidemiology of sports-related concussion in NCAA athletes from 2009-2010 to 2013-2014: incidence, recurrence, and mechanisms
Franchini E	11	Physical and physiological attributes of wrestlers: an update
Karnincic H	11	Lactate profile during Greco-Roman wrestling match
Nakazato K	11	Trunk muscle strength and disability level of low back pain in collegiate wrestlers
Oppliger RA	11	Weight loss practices of college wrestlers

Stout JR	11	Accuracy of near-infrared interactance instruments for estimating percent body fat in youth wrestlers
Oopik V	10	Effect of rapid weight loss on metabolism and isokinetic performance capacity - a case study of two well trained wrestlers
Timpmann S	10	Dietary sodium citrate supplementation enhances rehydration and recovery from rapid body mass loss in trained wrestlers

* the study selected was the most cited, except when the article was already listed as a representative study of other author given many studies were co-authored by these researchers (in this case the second most cited article was listed). Additionally, papers selected have included wrestlers as participants, and analyzed separately from other athletes, or were reviews specifically about wrestling. Two authors (Gabett TJ, n = 15 publications; and Johnston RD, n = 10 publications) were not included in this list as the term "wrestling" appeared in their publications but in the context of rugby matches.

Based on the most cited articles presented in Table 1, it is clear that investigations about weight loss and its effects, followed by techniques to determine body composition, were the main topic of the most prolific researchers in this field. Injuries of wrestlers taking part in multi-sport competitions, strength profiling of wrestlers, and physiological responses to wrestling were the other topics studied. It is likely that this scenario was determined by the high prevalence of rapid weight loss in wrestlers, and therefore, a practical problem faced by coaches and strength and conditioning professionals was investigated by researchers. It is important to note that these topics are similar to the ones reported by Millet et al. (2021) for Olympic sports in general, and wrestling specifically, i.e., physiology, injuries, training and testing, and performance, but did not include other topics such as psychology and biomechanics.

Figure 1 presents the number of wrestling-related publications per year, since the inception of Web of Science register (i.e., 1973) up to 2020.

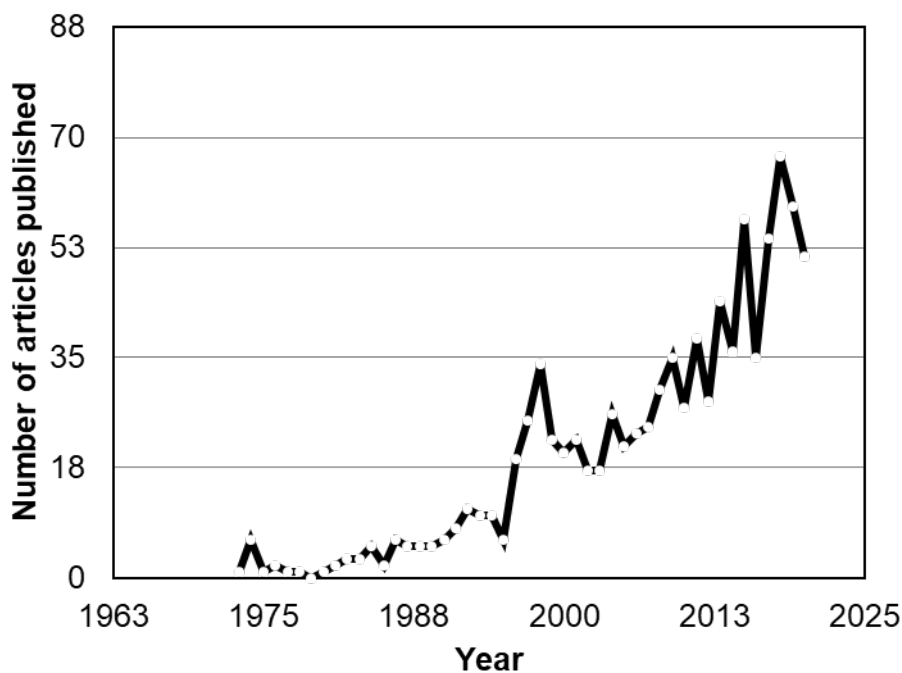


Figure 1: Number of wrestling-related articles published in Sport Sciences area and indexed in the Web of Science between 1973 and 2020.

Figure 1 indicates a steady increment in wrestling publication from the 1970's up to middle 1990's. Despite a great increase in 1997, this was followed by a subsequent decrease in early 2000's, and a new increment after 2009. The number of publications peaked in 2018 and presented a new decrease thereafter. Although it is difficult to explain the reasons for the variations observed in Figure 1, it is clear that wrestling-related research increased considerably in the last decade, which is similar to the findings observed in Olympic combat sports (Franchini et al., 2018) and Olympic sports in general (Millet et al., 2021). Therefore, it seems that Sport Sciences is consolidating as a scientific area, and wrestling is following this tendency, even though with a small percentage of papers when compared with other sports (e.g., team sports and American professional sports) (Millet et al., 2021).

Reading scientific articles can be a valuable source of knowledge to coaches, but the academic writing style may be a barrier to access the information within the papers (Williams and Kendall, 2007). To overcome this barrier clubs, federations and other wrestling organizations could set a scientific partnership with a researcher or have a person dedicated to constantly search for these articles and provide a summary of the findings and a more palatable form. Indeed, the International Network of Wrestling Research (INWR) is an initiative to provide research-based information related to wrestling, with more than 500 members from 89 countries (INWR, 2021). The INWR, in conjunction with United World Wrestling (UWW), has published the International Journal of Wrestling Science since 2011. Additionally, a special aspect of its website is the Annual Reviews and Compilations of Wrestling Research section, which presents a list of references published each year related to this sport. This is a initiative of Dr. David Curby (USA), who has been doing this compilation since 2005. Thus, this can be a valuable source for coaches, strength and conditioning professionals and researchers to find and select investigations in different scientific fields about wrestling, especially because it presents articles from different indexes sources and even non-indexed articles.

The Institute of Applied Training Science in Leipzig (IAT) has developed SPONET which is a training science search engine. The Institute for Applied Training Science (IAT), founded in 1992, is the central research institute for German elite and young athletes. It currently provides access to over 100,000 sport science articles. Wrestling is one of 59 sports for which a bibliographic database is provided. The database contains 3,182 relevant items related to Wrestling. Searches can apply the presented keywords (training control, long-term performance, build-up, perception, recovery, sport physiology, weightlifting, technique, junior elite sport, movement co-ordination, endurance, freestyle wrestling, peaking for a competition, training periodization, motivation, training, competition, Greco-Roman wrestling, tactics, movement, fatigue, sport psychology, performance diagnostics, coaching, training planning, speed strength, biomechanics, strength, nutrition), or you can search the database on your own.

Regarding the present search, the following journals published more than 25 articles about wrestling: Journal of Strength and Conditioning (n = 92), Medicine and Science in Sports and Exercise (n = 69), Archives of Judo (n = 48), American Journal of Sports Medicine (n = 45), Journal of Sports Medicine and Physical Fitness (n = 43), Journal of Athletic Training (n = 42), Physician and Sports Medicine (n = 32), Clinical Journal of Sports Medicine (n = 30), International Journal of Sports Medicine (n = 29), British Journal of Sports Medicine, and Human Sport Medicine (n = 25). Most of these journals are top-level Sport Sciences journals and therefore this indicates that high-level research has been conducted about wrestling. Thus, these journals can be a first choice for those interested in this type of research. Additionally, the wrestling-specific scientific journal the International Journal of Wrestling Science, which has been published since 2011 and 279 articles have been published in this open access journal. (INWR, 2021).

Concerning the countries where wrestling research was conducted, the present search indicated the following as the top 10 countries: United States of America (n = 436), Poland (n = 79), Turkey (n = 55), Australia (n = 52), Japan (n = 47), Russia (n = 39), England (n = 38), Brazil (n = 37), Iran (n = 33), and Canada (n = 31). This list is quite similar to that reported for countries conducting research about Olympic combat sports (Franchini et al., 2018), and includes countries with a long tradition and top performance in wrestling in the Olympic Games and World Championship. This confirms the hypothesis that Sport Sciences research is driven by the social relevance of specific modalities in some countries (Millet et al., 2021).

Finally, caution should be taken when considering these data because maybe other wrestling-like combat sports (e.g., sumo wrestling, arm wrestling and Asian mas wrestling) may have been counted in the total of articles, even though the number of such article may represent a small percentage of the total. Future searches should analyze each article, and determine the main topics investigated.

FROM RESEARCH TO INTERVENTION

Classically, Sport Science's goals have been established as to improve performance, to prevent injury, and to provide relevant information to coaches and practitioners to allow an intervention resulting in improved athlete's performance (Bishop, 2008). However, it is clear that those conducting research in universities have

a slightly different goal from those working directly with athletes, and this create a gap between research and intervention. The gap between investigations and interventions is likely caused by the highly specialized language used in academic journals, the difficulty to disseminate the scientific information to coaches, the conservative practices by some coaches (who avoid introducing modifications in their training program), and to the congested activities executed by coaches, resulting in lack of time to study (Bishop, 2008). Some strategies have been proposed to build a bridge between Sports Sciences and intervention, recommending the insertion of a sport scientist in the multidisciplinary technical commission working with athletes (Barlett and Trust, 2020). According to these authors, this would allow a better understanding by sport scientists about the modality, resulting in improved research questions, while providing evidence-based information to other professionals.

Considering the wrestling-related research described above, the following can be considered relevant for future investigations:

- (a) Training monitoring and training modeling - what are the best instruments to monitor wrestlers' training? How training monitoring variables may predict future performance? Is it possible to model the training responses based on training stimuli? How wrestlers' initial levels of physical fitness affect the response to training intensity and volume?;
- (b) Weight loss - How to educate athletes to avoid rapid weight loss processes? How to optimize the weight loss process and maximize the recovery between the weigh-in and the beginning of competition? What are the long-term effects of rapid weight loss on wrestlers' health, specially during the post-competitive career? What are the short- and long-term effects of rapid weight loss in the mental health of wrestlers? Although part of these aspects have been considered in some investigations, more information is needed, especially when considering the recent rule changes in wrestling (including the weigh-in being executed closer to the competition);
- (c) Physiological and biomechanics measurements during wrestling-specific actions - due to the nature of wrestling, the execution of physiological and biomechanics measurements is difficulty. However, the technology has been improving in these areas, and it is likely that in the near future it will be possible to conduct such measurements. This will provide relevant information for strength and conditioning training design;
- (d) Wrestling-specific test development - although some wrestling-specific tests are available, it is important to have specific tests to evaluate different physical capacities (e.g., aerobic power and capacity; anaerobic power and capacity; maximal isometric strength; maximal dynamic strength; strength-endurance). This may involve the development of specific ergometers and equipment;
- (e) Injury prevention - What are the best interventions to reduce injuries during wrestling training and competitions? How training intensity and volume affect the injury risk of wrestlers? How the competition calendar affects the injury risk? Is physical fitness - or a specific physical capacity - related to injury prevention?;
- (f) Teaching and learning - How beginner's wrestlers learn specific techniques? What are the best progressions to teach the techniques? The age wrestlers start to practice has an influence on their adherence to practice? How early specialization affect drop off rates in wrestling? How athletes evolve their technical skill along their careers?;

Certainly other relevant topics may be investigated, depending on several aspects, such as countries' economy, social representation of wrestling, wrestling culture (including number of practitioners and coaches), etc.

FINAL CONSIDERATIONS

Despite the long tradition of wrestling, Sport Sciences scientific research about this sport is at its beginning. It is likely that investigations in this area can provide valuable contributions to improve coaches, strength and conditioning professionals, and practitioners involved with wrestling. However, as for other sports, it is necessary that a stronger relationship be set between those working directly with wrestling and researchers. Even though this is not an easy task, the investment in this process may pay off.

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