AN EMPIRICAL STUDY ON THE ATHLETIC SHOE CONSTRUCTION FOR SPORTS

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Abstract : This work illustrates current views of athletic footwear analysis and development. It introduces approaches for the identification of athletic footwear necessities, displays procedures for the excellent analysis of athletic footwear, and proposes systematic structures for athletic footwear innovation. Thereby, the complexness of footwear necessities is displayed by addressing sport specific demands however conjointly by addressing completely different jock demands differentiated by their sex, age, ability level, and culture. The particular characteristics and mutual interaction of simulation, mechanical, biomechanical, athletic performance and perception analysis procedures of athletic footwear square measure introduced, mentioning the importance for comprehensive assessment of athletic footwear. The set of analysis procedures is the basic tool box throughout application of projected reactive and proactive athletic footwear innovation structures. Examples square measure provided for example the sensible relevancy of the theoretical framework provided.

IndexTerms **- Athletic footwear, Biomechanical, Racquet Sports**

I. INTRODUCTION

All footwear, thanks to its characteristic position between the pes and therefore the setting, acts as a man-made Interface. During this sense, footwear isn't restricted to shoes however conjointly refers to orthotics, insoles, socks, et al. like bandages or tapings.

As a man-made interface footwear influences actual locomotion and movements of its wearers, in addition as individual perception throughout everyday life and sports activity. Thereby, the foot with its anatomical and physiological structures and therefore the footwear with its construction characteristics exhibit a mutual interaction and kind a standard system that determines the practical advantage of a shoe for its user throughout its interaction with the setting.

The general purpose of sporting athletic footwear is to enhance comfort, performance and injury hindrance throughout sport specific movements, touching on natural and intuitive demands of athletes [7] [1] [13] (Figure 3). Fostering however conjointly levelling these demands throughout the creation of athletic footwear may be a key task for improvement of overarching Footwear practicality. Thereby, athletic footwear practicality describes the summed influence a sport shoe has on its user throughout execution of sport specific movements and relies on the collectively of its construction options.

FIGURE1: Relationship of Foot, Footwear and its Orthotics with the external environment

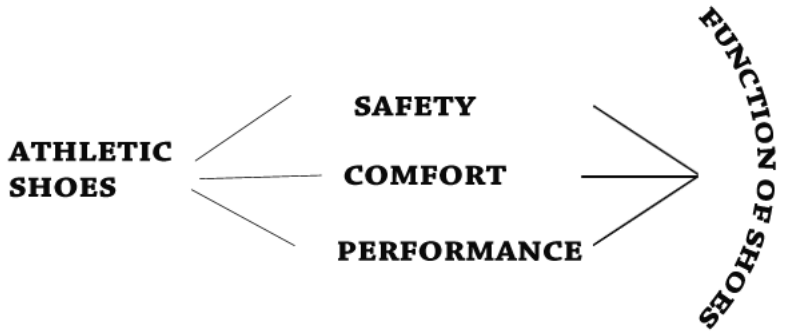

FIGURE 2:Different Functions of Athletic Shoes

Comfort of athletic footwear might dissent from a general understanding of comfort in everyday life. bound varieties of athletic footwear need sport specific construction, that support sensible performance or injury hindrance however that don't essentially give an honest feeling of comfort in its original sense (Slater 1985). As an example, alpine athletics, climbing, sprinting or association football shoes place athletes' feet during a rather slender house thanks to sport specific locomotion needs addressing individual performance and injury hindrance aspects. The house provided would in all probability not be thought-about snug by wearers in their general everyday life. However, throughout execution of sport specific movements individual shoes are perceived snug by athletes. Thus, comfort of athletic footwear must always be directed towards its sport specific operate and may be said as practical Comfort. During this sense, comfort of athletic footwear resembles an operate of objective factors like impact attenuation, in-shoe pressure, geometric work, et al. [6] [8] [14] [19] [25] [5] however conjointly a operate of subjective factors like individual expertise, expectations, demands, and preference [16].

Performance of athletic footwear is associate inherent facet within the sports world. as an example, association football shoes sanction active players to run and kick quicker, or trainers sanction active runners to run at lower metabolic value, are most popular over others [17] [24]. These or additional performance aspects may be said for different sports in addition. However, sports history documents that elite running performance may be achieved once competitive unshod as incontestable by Abebe Bikila, Olympic marathon champion in 1960, or by Emile Zola Budd, 5000 m record holder in 1984 [18]. Objective performance edges of athletic footwear may be quantified by direct and uncomplicated measurements, indicating the competitive advantage one shoe has over others. Subjective assessment of athletic footwear performance and its interpretation seems additional complicated. it's supported the neuroscience capability of athletes to receive and integrate external sensory performance stimuli, whereas being joined to athletes' expectations and previous expertise. during this sense, subjective assessment of athletic footwear performance was shown to coincide with objectively measured performance however conjointly to contradict it [17].

Injury hindrance manifests an additional necessary facet of athletic footwear, therefore constituting attention in sport shoe analysis concerning running footwear [4] [8] [13] [14], however conjointly concerning association football footwear and association football [19] [21] [25].While there's general agreement that athletic shoes ought to contribute to the hindrance of injuries, their opportunities to try and do thus are judged variously. as an example, the role of running footwear in injury hindrance continues to be not totally understood. this is often illustrated by current contentious discussions concerning the potential and quality of impact attenuation and rear foot motion characteristics of trainers directed towards the decrease of injury prevalence in runners throughout heel-toe running [10] [13] [15] [19].

II. ATHLETIC FOOTWEAR REQUIREMENTS

Athletic footwear requirements targeting participants in recreational sports, as well as professional and competitive athletes, must respect the official regulations imposed by the technical bodies for a given sport. Regarding soccer and running shoe construction the technical requirements of the Fédération Internationale de Football Association (FIFA), The Badminton World Federation

(BWF) and of the International Association of Athletics Federations (IAAF) are referred to. The frameworks of these technical bodies appear rather wide, leaving considerable room for construction variations of soccer and running footwear. Thus, numerous research findings for enhancement of shoe functionality may be implemented in the creation of soccer and running shoes while adhering to the rules imposed. In the following the official regulations are introduced. The requirements of soccer footwear are stated in Law 4 – The Players' Equipment of the Laws of the Game (FIFA 2014). The law states that footwear is compulsory equipment of players and that all equipment worn by players must not be dangerous to themselves or to other players. The requirements of running footwear are stated as part of the track and field regulations in Rule 143 (2, 6) – Clothing, Shoes and Athlete's Bib (IAAF 2013). The rule states that shoes may be worn at one or at both feet during competition, with their construction and technology, including attached appliances, not being allowed to provide any unfair assistance or advantage to the athlete. Competition footwear is meant to provide protection and stability to the feet and firm grip on the ground to athletes and shoes need to be approved by IAAF officials undergoing visual inspection prior to competition.

The regulations of FIFA, BFW and IAAF only set official boundary conditions for athletic footwear construction. However, it needs detailed locomotion and movement analysis of the key features of different sports as well as personal input of athletes and coaches to identify what athletic footwear actually should be. Objective biomechanical analyses allow quantifying the range of human locomotion and movement in which the shoe needs to function. Such analyses, for instance, provide insight into ground reaction force, joint motion, joint motion velocity, joint moment, muscle activity, surface pressure, in-shoe pressure, foot form, foot dimension, and foot function parameters [11]. Based on respective information, biomechanical profiles of sport specific movements are generated which may be unique for certain sports but which may also show overlapping characteristics, applicable for integration into various sports. An integrated understanding of the biomechanical background of universal types of human locomotion allows spreading gained knowledge into various types of shoe construction, as indicated for the push-off movement during acceleration.

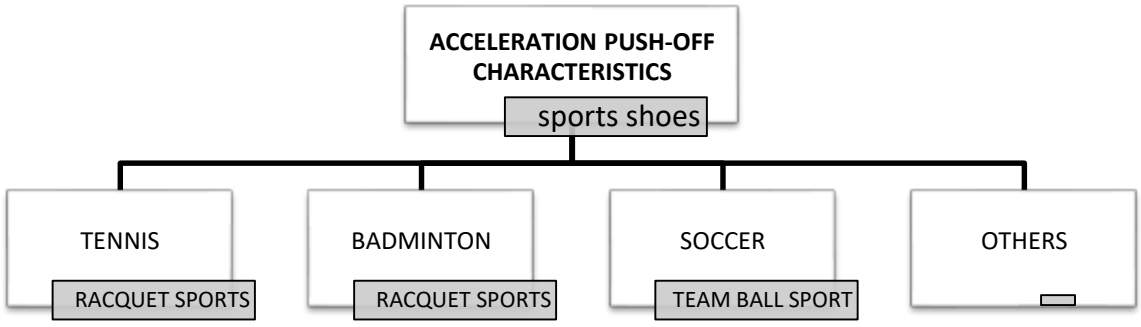

FIGURE 3: Sports shoe requirements based on standard movement of players

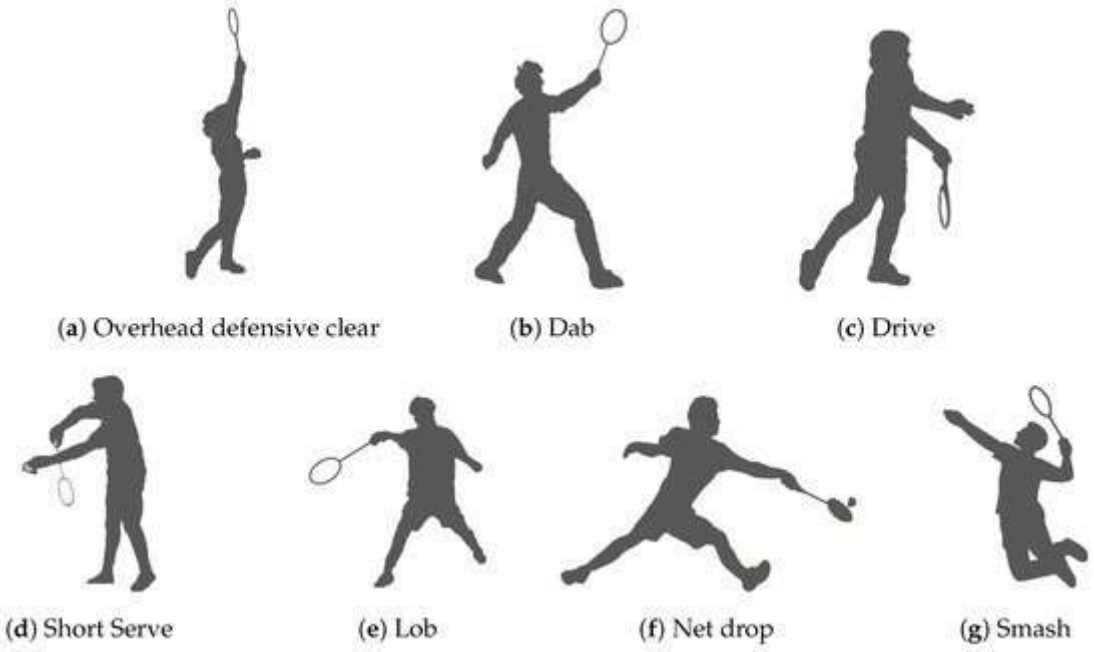

FIGURE 4: (Steels, 19 August 2020) Classified Strokes in Racquet sports

Similarly, integrated approaches to understand the effects of universal shoe construction features allow spreading gained knowledge into various types of sport shoes, as indicated for the characteristics of stud elements, traction and anti-skid properties.

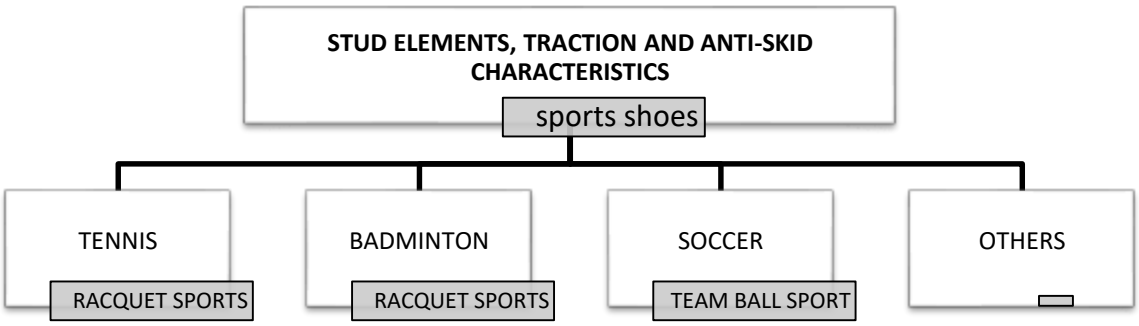

FIGURE 5: Sports shoe requirements based on standard construction.

Such integrated approaches allow the application of functional knowledge not exclusively directed to only one type of sport. Nevertheless, a detailed fine tuning of the general shoe concepts derived from such integrated approaches towards the specific sport these concepts are eventually applied to is regarded compulsory. While targeting subgroup inhabitants, detailed fine tuning concepts are required, for example male or female athletes. Respective anatomical and physiological characteristics, as well as locomotion patterns, were shown to vary between male and female runners, racquet sports and soccer players, which should be considered in athletic footwear creation [11] [15] [18].

Besides official regulations and movement related aspects the demands of athletes and opinions of coaches form a substantial part for identification of athletic footwear requirements. Their demands and opinions may vary depending on the type of sport but also due to subgroup specific needs reflecting sex, age, skill level, and culture [14] [21] [11]. Athlete questionnaire research has provided

comprehensive information of athletic footwear requirements for soccer, running, basketball, tennis, and gym training footwear [16] [17]. Across sports, comfort and fit have been identified as shoe features receiving the highest priority by athletes,then followed by more specific functional features required by respective sports.

Comprehensive analysis of athletic footwear

The analysis of athletic footwear, together with shoe example analysis throughout the shoe creation method, marks a vital field for making certain its quality. Valid and reliable analysis of athletic footwear may be a precondition for the systematic sweetening of its practicality. it's been recommended to guage athletic footwear comprehensively from varied views [21] [22] [23]. Currently, objective mechanical, biomechanical and athletic performance procedures similarly as subjective perception procedures ar incorporated throughout comprehensive analysis of athletic footwear of adequate standards.

These procedures ar supported by applying framework strategies permitting the reduction of human contestant dependent testing efforts. the various analysis procedures have their distinctive characteristics and supply specific insight into the practicality of athletic footwear. Thereby, objective analysis procedures indicate the particular alteration of human locomotion evoked by shoe modifications, whereas subjective variables indicate however these modifications ar perceived by athletes. Mechanical characteristics of sport shoes ar considered the overall origin for future biomechanical, athletic performance, and perception alterations. Thus, the modification of mechanical characteristics has to be accurately controlled and consistently organized so as to extend the chance of extracting precise tips for enhancing athletic footwear practicality. The relation of objective and subjective analysis parameters could show completely different patterns, that don't continually follow intuitive expectations and that haven't nonetheless been consistently delineated .

Innovation structures of athletic footwear

Athletic footwear innovation marks a vital field of sport shoe analysis. Thereby, innovation arises from varied directions like new and superior shoe material, technology, and producing processes, however additionally from new and superior useful footwear ideas. Innovative sport shoe ideas ar required to suit athletes in responding to dynamical environmental factors and to supply them with increased merchandise normally, increasing their performance. Such innovative shoe ideas could also be helpful by supporting or difficult human locomotion throughout competition or coaching situations. For the initiation of latest athletic footwear ideas, 2 innovation methods ar planned, associate extrinsically triggered reactive response structure associated an per se triggered proactive incentive structure.

To identify helpful footwear ideas, response structures react to dynamical environmental circumstances, whereas proactive structures rummage around for opportunities to enhance human locomotion supported its increased understanding. The common foundation of each innovation structures is outlined by the conviction that knowledge-based style and development efforts of athletic footwear ar superior to trial-and-error approaches. throughout application of those innovation structures increased data of human locomotion could also be retrieved from already existing sources, for instance scientific literature, patents, or others. increased data might also be generated by conducting initial baseline analysis, before feeding the data gained into innovative shoe ideas and also the future comparison of desired and actual shoe practicality.

An example for associate extrinsically triggered response approach of athletic footwear innovation is marked by analysis responding to the implementation of artificial football turf, eventually resulting in style and development tips for several football shoes [17]. because of changes within the official laws of the football game, the necessity for innovative sole configurations of football shoes became apparent, reacting to the environmental changes that occurred.

Examples marking the place to begin of per se triggered incentive approaches of athletic footwear innovation ar analysis efforts analyzing the consequences of consistently changed segmental midsole hardness of trainers [15] [13] [14]. These works were conducted to boost the understanding of the biomechanical and perceived interaction of the shoe with the foot and also the shoe with the surface throughout heel-toe running. future steps have to be compelled to incorporate the derived insight into additional advanced shoe prototypes, which may offer increased practicality to runners supported the insight generated.

Further initiatives marking beginning points of per se triggered incentive approaches of athletic footwear innovation ar analysis efforts directed to the understanding of human methods to barter unpredictable irregular surfaces [2] [8] [11]. These items of labor link views of motor performance and motor learning methods, into account of variability characteristics of human locomotion and movement. They suggests the advantages the rise of motor performance variability could have once evoked throughout athletic walking and running. more works recommend however innovative footwear constructions derived from such baseline analysis will simulate irregular surface circumstances throughout walking, running and coaching situations, thereby increasing the standard of athletes' coaching exposures.

III. RACQUET SPORTS

There are four main racquet sports (tennis, badminton, squash and table tennis), with some other racquet sports being played to a lesser extent. Racquet sports can be played with a net dividing the Players , in the case of squash, with the players moving in a common court area. The common aspect of racquet sports are that shots are played by competitors in alternation, forming rallies. There are singles and doubles games in all four main racquet sports. The purpose of this chapter is to review performance analysis research in racquet sports[12].The shuttlecock has an a typical trajectory, and the players perform specific movements such as lunging and jumping, and powerful strokes using a specific pattern of movement. The racquet sports require sports related musculoskeletal needs so as to adapt to stress associated with these sports performance. These adaptations can have led to positive changes like enhanced motor skills or negative like leading to foot injuries. There are different factors like player's overall health, skill level, training, previous injuries, playing patterns affect overall performance of athletes. External factors like footwear and court surface which too affects performance.

In racquet sports first most important stroke is service which requires coordinated movement of different parts of the body in rhythm so as to create maximum required speed, racquet position and trajectory. This rhythmic movements require extension of knee and hip joints leading to rotation of trunk followed by upper limb extension for the shot. This is referred as "Kinetic Chain"[27].The leg determines the success of the serve hence performance. Most of the players have foot back movement in which they leave the rear foot back during initial phase of racquet movement then swipe this foot round and frontward prior to strike , Foot-up movement in which players bring the back foot up to the front is another way some of players uses in the initial phase of impact[28]. There are four main racquet sports (tennis, badminton, squash and table tennis), with some other racquet sports being played to a lesser extent. Racquet sports can be played with a net dividing the players or, in the case of squash, with the players moving in a common court area. The common aspects of racquet sports are that shots are played by competitors in alternation, forming rallies. [16] Finally, physical aspects of performance can be investigated through analysis of rally lengths and estimates of game intensity.[12]

IV. LITERATURE REVIEW

As per the theory of [9], Few changes and modification are very essential in shoes to reduce the risks of possibility of any injuries as well as it also enhance the performance in basketball. The article in this paper is crucially describe the modification process of different types of shoes in basketball regarding to the movements. A search of four major databases for biomechanics research evaluating basketball shoe

construction/material returned 442 results. After removing duplicates and applying exclusion/inclusion criteria to the titles and abstracts, 20 articles were left for additional quality evaluation. Two reviewers independently confirmed 17 publications (n = 340 participants) that were included for review, with 95.5 percent agreement between their judgments. The outcomes were classified on the basis of following shoe modifications: (a) cushioning, (b) midsole hardness, (c) collar height, (d) outsole traction component, (e) forefoot bending stiffness and (f) shoe mass that influence lower limb biomechanics. The studies found that 1) better shoe cushioning or a softer midsole is linked to better impact attenuation in passive/unexpected situations, 2) high shoe collars are effective in improving ankle stability in jumping and cutting tasks, 3) increased shoe traction and forefoot bending stiffness can improve basketball jump, sprint, and/or cut performances, and 4) lighter shoe mass results.

As per the theory of [12], This review paper shows about the journey for a racquet sport science. In the initial time of racquet sport science, may be over 50 years ago, It can be easily map out the past experts researchers who risk their future by away from their parent academic discipline towards a virgin field of discovery due to their love of the game. They were successful in making the change and laying the groundwork for others to follow in their footsteps. They did indeed follow. Hundreds of people now had the opportunity to develop their scientific skills, as the pioneers had done, through the love of their sport, thanks to the expansion of educational opportunities in western society at the end of the twentieth century, combined with the advancement of technology and the availability of computers. The scientific conference was created to address the need to disseminate their results to the rest of the world, and it grew from humble beginnings into a venue for regular international meetings.

As per the theory of [24], It is essential to improve the entire equipment to enhance the performance of players. However, not all athletes area unit ready to like the new, ideal instrumentation, with some athletes performing arts worse. though the engineering is also sound, the interaction between the piece of apparatus, the contestant, and also the action is missing. The strictly system of the piece of apparatus becomes a biomechanical system once it's interacting with the contestant. analysis into the underlying mechanisms of performance in sport has relied heavily on biomechanical studies.

. The review of these studies has identified important performance and injury variables that can be influenced by sport equipment. This information serves as a foundation for equipment designers and developers to have a basic grasp of human performance. If the athlete–equipment interaction is not correctly addressed in the design process, even the best-engineered mechanical piece of athletic equipment can fail. It's important to evaluate how an athlete uses a piece of equipment, as well as how an athlete might modify or adapt to changes in the equipment's qualities. Research has offered awareness of the biomechanical limiting factors surrounding the influence of footwear traction on sports performance, using footwear qualities as an example. There is a lack of information on other aspects of footwear, such as cushioning and forefoot bending stiffness. As demonstrated during cycling, intrinsic musculoskeletal features, such as the force–length and force–velocity correlations of skeletal muscle, can be utilised through equipment design. Changes to equipment characteristics can vary an athlete's operating range within these relationships, allowing them to maximise force or power output, as demonstrated during the creation of the clap skate. Minor modifications to a piece

of athletic equipment can help individual athletes enhance their biomechanical qualities based on their own biomechanical characteristics.

According to the explanation of [26], Badminton is a popular sport for both amateur and professional players. Many biomechanical research have looked into badminton lunge performance, as good lunge performance can help you win the game. The current trends, research techniques, and parameters of interest in lower-extremity biomechanics in badminton lunges were discussed in this review. Methodology. From the earliest possible date through September 2020, databases such as Web of Science, Cochrane Library, Scopus, and PubMed were searched. All of the publications were checked by two separate writers, and 20 of them were selected for additional study. Using characteristics such as ground reaction forces, plantar pressure distribution, kinematics, and kinetics, the evaluated publications analysed differences among playing levels, footwear designs, and lunge directions/variations. Results. Elite badminton players had a higher medial plantar load, a more active knee and ankle approach (higher mechanical moment), and a higher impact attenuation capability than amateur players. Changes in footwear can affect comfort perception and movement mechanics, but it's unclear how these factors relate to lunging performance. The differences in lunge and instructions could explain the contradictory findings in kinematics. Future research could use an unexpected testing strategy as well as realistic movement intensity. They can look at inter-limb coordination, as well as the contributions and interactions of inherent and extrinsic factors in injury risk. Furthermore, the current findings may spur further research into whether some structurally designed footwear materials may hinder impact attenuation, proprioception, and performance.

As per the theory of [23], Long-distance running is known to cause joint overloading and raise cytokine levels, both of which are common symptoms of running-related ailments. To address this, footwear systems with cushioned midsoles are used to reduce harmful mechanical loads. The goal of this research was to see how athlete body mass affected the cushioning capability of technical footwear. An artificial heel was designed to mimic the impact pattern of a heel-strike runner, and an automated drop test was utilized to quantify shock attenuation. To imitate runners of various body masses and speeds, the impact mass and velocity were varied. The outcomes recommends that even while modern footwear is able of attenuating the shock waves occurring during foot strike, improper shoe selection could expose an athlete to high levels of peak stress that could provoke an abnormal cartilage response. The use of a weight-specific cushioning system could provide the best protection and, as a result, extend the time spent exercising, which is beneficial to keeping a robust immune system.

The goal of this analysis was to envision however contestant body mass affected the artifact capability of technical footwear. a synthetic heel was designed to mimic the impact pattern of a heel-strike runner, and an automatic drop check was utilised to quantify shock attenuation. To imitate runners of assorted body lots and speeds, the impact mass and speed were varied. The outcomes recommends that even whereas fashionable footwear is in a position of attenuating the shock waves occurring throughout foot strike, improper shoe choice might expose Associate in Nursing contestant to high levels of peak stress that might provoke Associate in

Nursing abnormal animal tissue response. the employment of a weight-specific artifact system might give the simplest protection and, as a result, extend the time spent exertion, that is useful to keeping a strong system.

V. CONCLUSION

This work referred to current perspectives of athletic footwear research and development regarding the general purpose of sport shoes, as well as regarding related requirements, evaluation procedures, and innovation strategies. Thereby, the origin of the perspectives provided is the notion that athletic footwear (as all footwear) resembles an Artificial Interface between its wearer and the environment, exhibiting a certain degree of Footwear Functionality. Substantial approaches to systematically enhance footwear functionality were introduced and further illustrated by examples of recently conducted original research. Among those, a number of racquet and running shoe research examples were explained in detail, highlighting specific interactions among the sport shoe, the foot, and the environment. For systematically modified racquet and running shoe constructions the effects on biomechanical, athletic performance and subjective perception parameters were examined. Thereby, the findings allowed the derivation of shoe features being suited to enhance performance of athletes when reasonably implemented in design and development efforts.

REFERENCES

[1]. Brauner, T., Zwinzscher, M., & Sterzing, T. (2012). Basketball footwear requirements are dependent on playing position. Footwear Science, 4, 191–198. doi:10.1080/19424280.2012.674980

[2]. Clarke TE, Frederick EC, Cooper LB (1983) Effects of shoe cushioning upon ground reaction forces in running. Int J Sports Med 4:247–251

[3]. efanyshyn DJ, Nigg BM (1997) Mechanical energy contribution of the metatarsophalangeal joint to running and sprinting. J Biomech 30:1081–1085

[4]. Fleischmann, J., Mornieux, G., Gehring, D., & Gollhofer, A. (2013). Medial compressible forefoot sole elements reduce ankle inversion in lateral SSC jumps. Journal of Applied Biomechanics, 29, 346–353. doi:10.1123/jab.29.3.346

[5]. Frederick, E. C. (1995, June 28- 30). Biomechanical requirements of basketball shoes. In M. Shorten, A. Knicker, & G. P. Bruggemann (Eds.). Proceedings of the second symposium of the ISB working group on functional footwear (18–19). Cologne: International Society of Biomechanics.

[6]. Hennig EM, Sterzing T (1999). The use of global positioning systems (GPS and DPGS) for the tracking of human motion, Proceedings 17. Congress of the International Society of Biomechanics, Calgary, AB, Canada.

[7]. Hennig EM, Sterzing T, Brauner T, Kroiher J (2005). The influence of sock construction on foot climate in running shoes, 7. Footwear Biomechanics Symposium, Cleveland, OH, USA.

[8]. Hennig EM, Sterzing T, Beierle T, Uttendorfer M (2005). Plantare und dorsale Berührungsempfindlichkeit des Fußes, Wahrnehmungsschwellen für Berührungs- und Vibrationsreize, Jahrestagung der DGfB/ biomechanica V, 55, Hamburg, Deutschland.

[9]. Lam, Gilbert W.K. & Kan, Wei & Chia, Jingyi & Kong, Pui. (2019). Effect of shoe modifications on biomechanical changes in basketball: A systematic review. Sports Biomechanics. 10.1080/14763141.2019.1656770.

[10]. Lam, Wing; Wong, Duo; and Lee, Winson, "Biomechanics of lower limb in badminton lunge: a systematic

[11]. Landry, S. C., McKean, K. A., Hubley-Kozey, C. L., Stanish, W. D., & Deluzio, K. J. (2009). Gender differences exist in neuro-muscular control patterns during the pre-contact and early stance phase of an unanticipated side-cut and cross-cut maneuver in 15-18 years old adolescent soccer players. Journal of Electromyography & Kinesiology, 19, 370–379. doi:10.1016/j. jelekin.2008.08.004

[12]. Lees, A. The evolution of racquet sport science—a personal reflection. Ger J Exerc Sport Res 49, 213–220 (2019).

[13]. Pearsall DJ, Hennig EM, Sterzing T (2002). The use of skin pre-tension to modify tibial bone acceleration estimates, Proceedings 4. World Congress Biomechanics, Calgary, AB, Canada.

[14]. Schubert, C., Oriwol, D., & Sterzing, T. (2011). Gender and age related requirements of running shoes: a questionnaire on 4501 runners. Footwear Science, 3, s148–s150. doi:10.1080/ 19424280.2011.575850

[15]. scoping review" (2020). Faculty of Engineering and Information Sciences - Papers: Part B. 4525.

[16]. Stefanyshyn DJ, Nigg BM (2000) Influence of midsole bending stiffness on joint energy and jump height performance. Med Sci Sport Exerc 32(2):471

[17]. Sterzing T, Hennig EM (1999). Measurement of plantar pressures, rearfoot motion and tibial shock during running 10 km on a 400 m track, Proceedings 4. Footwear Symposium, Canmore, AB, Canada.

[18]. Sterzing T, Hennig EM (2005). Plantare Druckverteilungsanalyse fußballspezifischer Bewegungen und ihre Bedeutung für die Fußballschuhkonstruktion, Jahrestagung der DGfB/ biomechanica V, 113, Hamburg, Deutschland

[19]. Sterzing T, Hennig EM (2003). Stability in soccer shoes: The relationship between perception of stability and biomechanical parameters, Proceedings of the 5. World Congress on Science and Football, Lisbon, Portugal.

[20]. Sterzing T, Hennig EM, Pearsall D (2002). Measurement of inversion and eversion movements of the foot by using a position transducer, Proceedings 4. World Congress of Biomechanics, Calgary, AB, Canada.

[21]. Sterzing T, Muller C, Hennig EM, Milani TL (2009) Actual and perceived running performance in soccer shoes: a series of eight studies. Footwear Sci 1(1):5–17

[22]. Sterzing T, Uttendorfer M, Hennig EM (2004). Foot mapping of vibration sensitivity thresholds, Proceedings 13. Biennial Conference of the Canadian Society for Biomechanics, Halifax, NS, Canada.

[23]. Tsouknidas, M. Pantazopoulos, D. Sagris, D. Fasnakis, S. Maropoulos, F. Arabatzi, N. Michailidis, "The Effect of Body Mass on the Shoe-Athlete Interaction", Applied Bionics and Biomechanics, vol. 2017, Article ID 7136238, 9 pages, 2017. https://doi.org/10.1155/2017/7136238

[24]. Wannop, John & Stefanyshyn, Darren. (2015). Biomechanics research and sport equipment development. Sports Engineering. 18. 10.1007/s12283-015-0183-5.

[25]. Willwacher S, Konig M, Potthast W, Bruggemann G-P (2013) Does specific footwear facilitate energy storage and return at the metatarsophalangeal joint in running? J Appl Biomech 29:583–592

[26]. Wing K. Lam, Wei H. Kan, Jingyi S. Chia & Pui W. Kong (2019): Effect of shoe modifications on biomechanical changes in basketball: A systematic review, Sports Biomechanics, DOI: 10.1080/14763141.2019.1656770

[27]. Fundamentals of Tennis by Stanley Plagenhoef ,0133446069 (ISBN13: 9780133446067) Published July 24th 1970 by Prentice Hall

[28]. Elliot, BC and Wood (1983) :The Biomechanics of the Foot-up and Foot-back Tennis service Techniques. The Australian Journal of Sport Science.