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INNOVATIVE SPORT TECHNOLOGY THROUGH CROSS-DISCIPLINARY RESEARCH: FUTURE OF SPORT SCIENCE

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ABSTRACT

This paper provides an overview of the advantages and disadvantages of innovative sport technology brought about by cross-disciplinary research in sport, engineering, medical and material sciences. Sport technology has subsequently contributed greatly to the enhancement of epidemiology, prevention and management of injuries, management of non-communicable diseases, physical activity and sport performance. The debate raging between sport scientists and academics pertaining to the greater amount of attention paid to sport technology and cross-disciplinary research in sport and the diminished quality and quantity of subject matter is highlighted. The paper also raises the following ethical question: Should only affluent elite athletes have the opportunity to capitalise on this technology? Is this jeopardising the success of less affluent athletes?

***Key words*:** Sport technology; Cross-disciplinary.

INTRODUCTION

The 21st Century has seen more people than ever before participating in sport and physical activity. Koffi Annan, the UN Secretary General, has described sport as the universal language of the world that unites its entire people (Fuss *et al*., 2008). The increased interest and participation by both athletes and spectators have enabled sport to evolve into a global business, worth approximately USD 600 billion and growing (Fuss *et al*., 2008). The quest for sport supremacy has directed millions to innovative sport technological developments, particularly epidemiology, prevention and management of injuries, management of non-communicable diseases, physical activity and human performance. These sport technological developments have come about through collaborative efforts of engineers, sport, medical and material scientists resulting in cross-disciplinary, inter-disciplinary and eventually trans-disciplinary research **(**Mirollo *et al*., 2008).

Many sport scientists and academics (Costa, 2005; Rikli, 2006; Graham & Hipp, 2014) agree that there is a need for innovative sport technological developments through collaborative cross-disciplinary research. Other authors are resistant to the application of cross-disciplinary research in sport, recommending that the sport fraternity should rather improve on the quality of basic sport science research (Polak, 1977; Rink, 2007; Vertinsky, 2009). The current paper provides an overview of the advantages and disadvantages of innovative sport technological developments brought about by cross-disciplinary research in sport, engineering, medical and material sciences. The paper also discusses the different types of cross-disciplinary research that facilitates the advancement of sport technology. Important ethical questions are presented, pertaining to general accessibility of expensive sport technology.

METHODOLOGY

The standard practices for systematic reviews (PRIMSA) was followed. The definitions were guided by the PRIMSA checklist for participants, interventions, comparisons, outcomes and study designs (PICOS). The participants or focal theoretical areas concern sport technology. The intervention was not necessarily a therapeutic intervention, but is interpreted as an exposure, namely sport technology research and the comparison in various articles were specific to sport and exercise science.

The outcomes of interest were: (i) sport technology; (ii) sport kinesiology technology; (iii) sports medicine technology; (iv) cross-disciplinary sport technology;(v) cross-disciplinary research in sport science; (vi) cross-disciplinary research in kinesiology; and (vii) cross-disciplinary research in physical education. The exclusion criterion was publications prior to 2005. A literature searches of peer-reviewed and professional journal publications were conducted, in the following search engines: PubMed, Medline; Science Direct; Ebscohost; Biomed; CINAHL; Embase; and Google Scholar. Key search words were directly related to the outcomes.

RESULTS

Thirty-three English publications were identified, but after the exclusion criterion was applied, only 13 were finally selected for this review. Table 1 reflects the opinions that either support or refute sport technological developments via the application of cross-disciplinary research. Ten papers supported the sport technological development via the cross-disciplinary sport research, while 1 refuted its application in sport science research and the other 2 presented the advantages and disadvantages of cross-disciplinary sport research.

DISCUSSION

The discussion is presented in the following categories: the relationship between innovative sport technology and cross-disciplinary research; the evolution of cross-disciplinary research; sport research; pragmatists against sport technology and cross-disciplinary sport research; and is the use of advanced sport technology unethical? Sport research is expanded further by addressing: sports medicine technology; innovative sport technology management of non-communicable diseases and physical activity; and sport technology enhancing sport performance.

Relationship between innovative sport technology and cross-disciplinary research

Innovative sport technological developments require the collaborative efforts of specialist scientists in sport, engineering, medical and material sciences. These collaborative research efforts are known as cross-disciplinary research (OECD, 1998). The inclination towards a greater specialisation in science and the necessity to combine knowledge from different disciplines to resolve problems are the underlying reasons for cross-disciplinary research.

Table 1. **OPINIONS ON SPORT TECHNOLOGICAL DEVELOPMENTS**

Authors	**Year**	**Type of research**	**Findings**
Chi *et al*.	2005	Qualitative Review	The authors' intention was to encourage and highlight new cross-disciplinary research and to arouse the readers' interest in understanding how computer engineering can be applied in sport.
Costa	2005	Qualitative review	The Delphi study proposes stronger research in cross-disciplinary sport science fields, to strengthen the application of theory in practice.
Hoods	2005	Qualitative Review	A critical review of revolutionary sport technological development of prostheses that enables lower limb amputees to competitively participate in sport.
Moor	2005	Qualitative Review	The author recommends that the sport research fraternity should establish acceptable guidelines if the application of new cross-disciplinary technologies is going to become the norm.
Wallace	2005	Qualitative Review	The author presents the advances in sport technology and positive impact on sport research.
Rikli	2006	Qualitative Review	The author embraces the application of engineering in sport research.
Gill	2007	Qualitative Review	The author embraces the application of engineering in sport research.
Rink	2007	Qualitative review	The author's primary objection against cross-disciplinary sport technological research is the development of inert sport science knowledge, which adversely influences sport science curricula.
Dzewaltowski	2008	Qualitative Review	The author argues that there is an eminent need for cross-disciplinary technological development in sport to present a counter offer to the more attractive sedentary option facilitated by commercial technology.
Fuss *et al*.	2008	Qualitative editorial	The authors are of the opinion that advances in sport technology through cross-disciplinary research, deepens the understanding of the particular needs of sport. This paper embraces the application of cross-disciplinary sport research.
Vertinsky	2009	Qualitative review	The review presents the advantages and disadvantages of cross-disciplinary sport research.
Graham & Hipp	2014	Qualitative review	The authors state that additional cross-disciplinary research should be adopted for the promotion of physical activity and sport.
Goertzen *et al*.	2015	Systematic Review	The authors embrace the application of cross-disciplinary sport research.

Evolution of cross-disciplinary research

The importance of cross-disciplinary research is widely recognised because of its creativity, progress and innovation, which have led to many intellectual breakthroughs in modern times. The evolution of the concept of cross-disciplinary research began with multi-disciplinary, then progressed into inter-disciplinary and finally trans-disciplinary research (OECD, 1998). In multi-disciplinary research, the subject under study is approached from different disciplinary perspectives, but integration is not accomplished. Inter-disciplinary research leads to the creation of a theoretical, conceptual and methodological identity.

Finally, trans-disciplinary research progressed further, to a convergence of disciplines accompanied by a mutual integration of disciplinary epistemologies (Van den Besselaar & Heimeriks, 2001). The need for cross-disciplinary research has resulted in the formulation of the bibliometric methodology. Bibliometric methodology provides a general overview of all scientific disciplines, with specific attention to their interrelation (Morillo *et al*., 2002). Graham and Hipp (2014) have reported that cross-disciplinary research is considered the best way to review and analyse practical research topics. They have reported the following benefits of cross-disciplinary technological research:

- Increasing the validity of outcome measures and findings;
- Simplifying the analysing data significantly;
- Improving the on-going, systematic collection and analyses of sport and physical activity;
- Allowing researchers to cope with analyses of large data sets by using cyber infrastructure; and
- Increasing the credibility of sport and physical activity findings among other health disciplines.

The words of Graham and Hipp (2014:2) aptly describe the need for cross-disciplinary research: “Undoubtedly, additional technologies from other scientific disciplines must be adopted for physical activity and sport measurement”.

Sport research

Sport research predominantly focuses on epidemiology, prevention and management of injuries, physical activity and technological management of non-communicable diseases. There is an increasing amount of research in the field of sports technology related to human performance. Cross-disciplinary sport research provides a panoramic view to various sport dilemmas, thereby producing the most effective solution. The subsequent discussion will provide examples of innovative sport technology improving the quality of sports medicine management, management of non-communicable diseases and physical activity and performance enhancement.

Sports medicine technology

The latest cutting edge sports medicine technology allows the epidemiologist to study the pathophysiology, early signs and symptoms, pathomechanics and severity of sport injuries thereby enabling the prescription of: (1) effective preventive strategies to combat the occurrence of these injuries; and (2) effective injury management. An example of advanced sports medicine technology is the musculoskeletal ultrasound that is being used to determine the incidence of muscular, skeletal and other soft tissue damage incurred from sport and physical participation, without invasive surgery. The musculoskeletal ultrasound provides a detailed view of visceral organs and tissue, allowing precise diagnosis of tendon tears, muscle abnormalities (atrophy and hypertrophy), tumours that may exist in visceral soft tissue and rheumatoid arthritis and other inflammatory diseases (Lento & Primack, 2008).

Due to this innovative sports medicine technology, sports medicine practitioners are now able to confirm and aid clinical diagnoses, as well as monitor structural response to interventions. It also has therapeutic uses, such as ultrasound guided infiltrations. The use of ultrasound definitely aids clinical management of athletes, thereby improving their return to play. Another example of sports medicine technology is platelet-rich plasma therapy that helps to heal, build tissue and stop bleeding (Mishra *et al*., 2009). Platelet-rich therapy takes advantage of the natural healing process, but at a quicker rate. Blood is drawn from the injured athlete; thereafter the platelet-rich plasma is separated. This plasma is then re-injected into an injured area, which promotes faster and more effective healing. Risks of rejection and/or adverse effects of the treatment are minimal, since the platelets come from the patient's own blood. Additional benefits also include decreased inflammation and pain, increased tissue repair, increased bone density and improved development of new blood cells (Kon *et al*., 2009). Platelet-rich therapy has successfully contributed to the quick recovery of tendon and muscle strains and ligament sprains (Kon *et al*., 2009; Mishra *et al*., 2009).

A third example of innovative sport technology injury prevention is motion digital analyses. Athletes can run, swim, cycle or perform their respective sport activity, which is digitally recorded. Thereafter, the kinesiologist reviews the footage to identify the pathomechanics of the athlete's kinesiology by measuring anatomical angles and joint range of motion to determine potential risk and severity of injury (Wallace, 2005). Motion digital analyses have successfully identified abnormal pitching patterns of baseball pitchers with shoulder injuries. This information has helped sports medicine practitioners to identify abnormal force couple relationships between internal and external rotator cuff muscles of the injured pitchers. Now motion digital analyses are frequently used to identify abnormal pitching patterns among adolescent and professional baseball pitchers in an attempt to prevent injury (Brukner & Khan, 2012).

Innovative sport technological management of non-communicable diseases and physical activity

Sport technological development, such as the smartphone fit application has the potential to transform low intensity exercise into supervised controlled moderate intensity. People can now record their walking and/or running velocity, heart rate and body mass index (BMI) (Adams *et al*., 2014, Maddison *et al*., 2014). The smartphone fit application also allows the person to calculate their desired training target heart rate range and BMI. The fit application motivates people to convert slow walking and running to faster walking and/or running, in an attempt to become fitter in a supervised controlled manner. People use the heart rate and BMI applications to determine their progress (Adams *et al*., 2014; Maddison *et al*., 2014). The use of such technology has also demonstrated to be an effective injury prevention tool. Obese, hypertensive and cardiac patients when exercising alone have used the smartphone fit application to set specific American College of Sport Medicine (ACSM) guidelines. Correlating their own heart rate ranges and associated walking velocity to the ACSM guidelines may prevent over exertion and injury (Adams *et al*., 2014, Maddison *et al*., 2014). This technology has proven to be safe, cost effective (eliminates the cost of biokineticists) and educational (increases the patient's knowledge on how to exercise safely, in a controlled manner to reduce risk of injury).

Dzewaltowski (2008) has warned that there is an urgent need for sport technological development to present an attractive counter-offer against alluring sedentary alternatives, such as play station and video games that lead to a sedentary lifestyle and decreased quality of life. The fitness industry has incorporated computer technology into equipment displays. In the 1990s, Life Fitness integrated its Life Cycle to the game Super Nintendo. The faster you pedal, the faster your counterpart on the video game screen moves, which encouraged patrons to increase the intensity of their workouts (Chi *et al*., 2005). This innovative idea capitalised on the competitive nature of a person, motivating them to cycle faster, thereby improving their aerobic capacity, muscle strength and endurance. These studies underscore the benefits of combining sport technology, physical activity and management of non-communicable diseases.

Sport technology enhancing sport performance

Presently, engineers, medical, material and sport scientists have developed new exciting sport technology via collaborative cross-disciplinary efforts aimed at enhancing human sport performance (Fuss *et al*., 2008). An outstanding example of the benefit of advanced sport technology is the critical review of the revolutionary development of prostheses by Hoods (2005), which highlights the engineering feat that enabled double leg amputee Oscar Pistorius to run nearly as fast as able-bodied athletes. The engineering and sport performance accolades were awarded for the development of a uniquely designed prosthesis that enhanced the athlete's aerodynamics, thereby improving his biomechanics allowing him to run faster. The engineering and material science triumph was the development of a light weight, but strong prostheses. The light weight of the prostheses successfully supported the athlete but also decreased the athlete's total body mass, which facilitated greater force propulsion per unit of body mass over a given distance, resulting in a faster running velocity (Hoods, 2005).

The modern bicycle has undergone many innovative engineering and sport technological changes, as seen in the development of specialised wheels, pneumatic tyres, extra sensitive braking system and pedals, aimed at increasing stability and rigidity, all of which improve the aerodynamics of a cyclist leading to enhanced performance (Wallace, 2005). The light weight frame decreases the total body mass of the cyclist and bicycle, thereby increasing the force propulsion per body mass unit. The revolutionary bicycle design improved the aerodynamics of the cyclist, which has contributed to faster cycling velocities.

Pragmatists against sport technology and cross-disciplinary sport research

The primary objection to sport technology development derived from cross-disciplinary sport research is the concept of inert knowledge. Inert knowledge can be described using the following analogy: When someone asks you the time, you do not explain to them how a watch is made. Inert sport knowledge is information, which students can express, but is of minimal value. It is the process of understanding sport concepts, which does not increase their knowledge for effective problem-solving (Polak, 1977). Rink (2007) has reported that inert knowledge has crept into the sport science, kinesiology and physical education content. The cause of this inert knowledge can be traced to a knowledge explosion that has led to over-specialisation in trans-disciplinary of sport science and other health-related fields. Polak's (1977:7) remark aptly describes the situation, "We know more and more about less and less". Basic knowledge in the discipline of sport science has been replaced by cross-disciplinary content because of the great interest in innovative sport technology. Rink (2007) has suggested that many sport science students can explain Krebs cycle, but are unable to prescribe appropriate exercises to improve cardiovascular endurance. Therefore, Rink (2007) and Vertinsky (2009) have recommended that sport science should focus primarily on research in this sport performance domain to enhance the knowledge of students of this field.

Is the use of advanced sport technology unethical?

Professional sport is a competitive occupation, which mandates millions of dollars and hours invested to improve performance (Tadepali *et al*., 2011). Both recreational and elite athletes are willing to invest a great deal of their time, effort and money to improve their performance. The ideal design of sport equipment requires the amalgamation of various disciplines for enhanced sport performance and injury prevention. The combined efforts of material scientists, mechanical engineers, physicists, anatomists, sport physiologists and biomechanists produce an advanced product (Froes, 1997). A prime example of how sport technology has improved sport performance is the shorter completion times of endurance running. Spiridon Loues won the first Olympic marathon in a time of two hours and fifty-nine minutes. Almost a century later the Olympic marathon record of Samuel Wanjiru was two hours, six minutes and thirty-two seconds, which is a 30% improvement. Much of this improvement is attributed to the changes in foot-wear, clothing apparel and improved training programmes (Froes, 1997; Tadepali *et al*., 2011).

The use of sport technology has proven that performance can be enhanced, but raises important fundamental ethical questions. The first question being, where should the proverbially line be drawn? Froes (1997:18) has postulated the following pertinent question: "Are the days of strenuous conditioning and natural supplementation the ideology of a by-gone era?"

The cost of high-tech ergogenic sport equipment is exorbitant. The latest, cutting edge sport technology is capital intensive, which is naturally only available to affluent elite athletes. Prosthetic devices that enable amputee athletes to be catapulted forward more efficiently than if the person were running on their own natural limbs, cost approximately R500 000 (McGimpsey & Bradford, 2013). Although ergogenically superior, the disc wheels were initially banned from Olympic bicycle competition, because they were expensive and beyond the financial means of most cyclists (Lee & Park, 2015). Wheel-chair basketball, rugby and tennis have seen drastic revolutionary wheel-chair design modifications. The modern tennis wheel-chairs have sharply slanted back wheels so that the player is able to change direction rapidly without capsizing (Sindall *et al*., 2013). The seat height of the wheel-chairs of basketball forwards have been raised to enhance their scoring, while the guards' wheel-chairs have an inclined seat to facilitate quick change of direction (Sindall *et al*., 2013). The cost of these special sporting wheel-chair modifications ranges from R50 000 to R70 000 per chair (Sindall *et al*., 2013). Wallace (2005) has posed the question of whether it should be allowed that competition at the highest level to be restricted to athletes who can afford high tech sport equipment. Moor (2005) recommends that the sport research fraternity needs better ethical guidelines if the application of innovative sport technologies is going to become the norm.

CONCLUSION

Innovative sport technology improves the quality and effectiveness of epidemiology, prevention and management of injuries, physical activity, management of non-communicable diseases and human performance. However, the sport governing federations should provide direction with regard to the ethical questions related to whether the sport supremacy of elite competitors is dictated by financial affluence, or not.

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REFERENCES

ADAMS, M.M.; DAVIS, P.G. & GILL, D.L. (2014). A hybrid outline intervention for reducing sedentary behaviour in obese women. *Frontiers Public Health*, 1: Article 45 (online).

BRUKNER, P. & KHAN, A. (2012). *Clinical sports medicine* (3rd ed.). New York, NY: McGraw Hill.

CHI, E.H.; BORRIELLO, G.; HUNT, G. & DAVIES, N. (2005). Pervasive computing in sports technology: Guest editor's introduction. *IEEE (Institute of Electrical and Electronics Engineers) Pervasive Computing*, 4(3): 22-25.

COSTA, C.A. (2005). The status and future of sport management: A Delphi study. *Research and Reviews*, 19(2): 117-142.

DZEWALTOWSKI, D.A. (2008). Emerging technology, physical activity and sedentary behaviour. *Exercise and Sport Sciences Reviews*, 36(4): 171-172.

FROES, F.H. (1997). Is the use of advanced materials in sport equipment unethical? *Journal of Motion*, 49(2): 15-19.

FUSS, F.K.; SUBIC, A. & MEHTA, R. (2008). The impact of technology on sport: New frontiers. *Journal of Sport Technology*, 1(1): 1-2.

GILL, D.L. (2007). Integration: The key for sustaining kinesiology in higher education. *Quest*, 59(3): 270-286.

GRAHAM, D.J. & HIPP, J.A. (2014). Emerging technologies to promote and evaluate physical activity: cutting-edge research and future directions. *Frontiers in Public Health*, 2: Article 66 (online).

GOERTZEN, L.; HALAS, G.; ROTHNEY, J.; SCHULTZ, A.S.H.; WENER, P.; ENNS, J.E. & KATZ, A. (2015). Mapping a decade of physical activity interventions for primary prevention: A protocol for scoping review of reviews. *JMIR (Journal of Medicine Internet Research) Research Protocols*, 4(3): e91.

HOODS, M. (2005). Running against the wind. *IEEE (Institute of Electrical and Electronics Engineers) Spectrum Magazine*, 42(6): 13-14.

KON, E.; FILRADO, G.; DELCOGLIANO, M.; LO PREIESTO, M.; RUSSO, A.; BONDI, A.; DI MARTINO, A.; CENCACCHI, A.; FORNASI, P.M. & MARCACCI, M. (2009). Platelet rich plasma: New clinical application. A pilot study for treatment of jumper's knee. *International Journal of Cared Injured*, 40(6): 598-603.

LEE, C.K. & PARK, Y.J. (2015). Carbon and binder free air electrodes composed of Co3O4 nanofibers for Li-air batteries with enhanced cyclic performance. *Nanoscale Research Letters*, 10: Article 319 (online).

LENTO, P.H. & PRIMACK, S. (2008). Advances and utility of diagnostic ultrasound in musculoskeletal medicine. *Current Review in Musculoskeletal Medicine*, 1(1): 24-31.

MADDISON, R.; PLAEFFLI, L.; STEWART, R.; KERR, A.; JIANG, Y. & RAWSTORN, J. (2014). The HEART mobile phone trial: the partial mediating effects of self-efficacy on physical activity on cardiac patients. *Frontiers Public Health*, 2: Article 56 (online).

MCGIMPSEY, G. & BRADFORD, T. (2013). Limb prosthetic services and devices. Critical unmet need: Market analysis (White Paper). Worcester, MA: Bioengineering Institute Centre for Neuroprosthesis, Worcester Polytechnic Institution. (34 pp.)

MISHRA, A.; WOODRALL, J. & VIERIA, A. (2009). Treatment of tendon and muscle using platelet rich plasma. *Clinical Sports Medicine*, 28(1): 113-125.

MIROLLO, F.; BORDONS, M. & GOMEZ, I. (2008). Interdisciplinarity in science: A tentative typology of discipline and research areas. *Journal of American Society for Information Science and Technology*, 54(1): 1237-1249.

MOOR, J.H. (2005). Why we need better ethics for emerging technologies? *Ethics and Information Technology*, 7(3):111-119.

OECD (ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT) (1998). *Interdisciplinarity in science and technology.* Paris (France): OECD, Directorate for Science, Technology and Industry.

RIKLI, R.E. (2006). Kinesiology. A homeless field: Addressing organizations and leadership needs. *Quest*, 58(3): 288-309.

RINK, J. (2007). What kinesiology is of most worthy? Perspectives on kinesiology from pedagogy. *Quest*, 59(1): 100-110.

POLAK, F. (1977). *Slow motion men.* Amsterdam: Elsevier.

SINDALL, P.; LENTON, J.P.; MALONE, L.; DOUGLAS, S.; COOPER, R.A.; HIREMATH, S.; TOLFREY, K. & GOOSEV-TOLFREY, V. (2013). Effect of low compression on wheelchair tennis match play. *International Journal of Sports Medicine*, 35(5): 424-31.

TADEPALI, S.C.; ERDEMIR, A. & CAVANAGH, P.R. (2011). Comparison of hexahedral and tetrahedral elements in finite element analysis of the foot and footwear. *Journal of Biomechanics,* 11(12): 2337-2343.

VAN DEN BESSELAAR, P. & HEIMERIKS, G. (2001). Disciplinary, multidisciplinary, interdisciplinary: Concepts and indicators. In: Proceedings *ISSI (International Society for Scientometrics and Informetrics) Conference on Scientometrics and Informetrics* (pp.1-24). Sydney (Australia): High Tech News, International Society for Scientometrics and Informetrics.

VERTINSKY, P. (2009). Min the Gap (or mending it). Qualitative research and interdisciplinarity in Kinesiology. *Quest*, 61(1): 39-51.

WALLACE, E. (2005). "The role of technology in sport". Sport Editorial. University of Ulster. Hyperlink: [www.ulster.ac.uk/scienceinsociety/technologyinsport.html]. Retrieved on 25 July 2015.

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