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A Review of biomechanical research for Footwear Outsole Stud development in Soccer

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국문요약

축구화 겉창 스터드 개발에 있어서 생체역학적 연구의 고찰

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본 연구는 축구화 겉창의 스터드개발시 운동역학적 연구가 스터드개발에 어떻게 영향을 끼치었는가를 국외 선행연구문헌을 고찰함으로서 그 과정을 발견하는데 그 목적을 두었다. 지난 70년간 축구화 스터드가 연구개발되는 과정에서 압력분포측정 실험 및 기타 상해유발요인을 분석함으로서 스터드의 형태을 변화시키는 과정에 있어서 축구장 바닥과 축구화 겉창과의 마찰력이 중요한 변수로 작용하였다. 징이 선수들의 미끄럼을 방지하고 순발력을 향상시켜 경기력 향상에 결정적인 도움을 준 것이다. 이후 징박힌 축구화가 보편화하면서 선수들은 공격수냐 수비수냐 또는 잔디 상태에 따라 징의 개수와 길이가 다른 축구화를 신게 되었는데, 그라운드 컨디션에 따라 신발이 개발되었다. 축구화는 징의 종류에 따라 길고 푹신한 잔디(5~7월 잔디)에 신는 SG(soft ground)형, 짧고 단단한 잔디(가을철 잔디)에 적합한 FG(firm ground)형, 인조잔디나 아주 짧은 잔디에 좋은 터프(Turf)형, 맨땅에 쓰는 HG(hard ground)형으로 대별되는데, SG형은 15㎜가 넘는 마그네슘 징을 6개 박는데 순발력과 파워를 극대화하기 때문에 수비수에 어울리는 스타일이다. 짧은 폴리우레탄 징 12개를 다는 FG형은 넓은 그라운드 접촉면을 이루면서도 잔디에 깊게 박히지 않아 유연성을 필요로 하는 공격수와 미드 필더들에게 애용된다.

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그라운드 상황이 좋지 않은 곳에서 뛰는 국내 고교, 대학 선수들은 12개의 징이 달린 축구화를 선호한다. 스터드가 많을 수록 그라운드에 닿는 면적이 넓어 안정감도 있고 발목이 꺾이는 현상을 줄여주기 때문이다.

지금까지의 연구현황은 압력분포 및 지면반력실험을 이용한 결과치를 이용하여 새로운 타입의 축구화 스터드의 개발결과를 기존결과와 비교분석하여 상해유발발생요인이 적은 스타일의 스터드를 선호하였다.

이에 향후 연구개발시 운동역학적 연구의 디자인시 상해유발요인분석과 운동역학적 연구결과의 조합을 결과를 비교분석해서 국내에서도 축구화 겉창 스터드 연구개발시 경기력을 향상시키고, 상해유발요인을 감소시킬수 있는 연구디자인이 지속되는 것이 중요하다고 사료된다.

주제어 : 축구화, 운동역학, 스터드, 마찰력

I. Introduction

Korean's soccer is one of the most popular spectator and participant sports, but the biomechanics of its development for soccer shoes have not been extensively studied, perhaps because the inter-communication for outsole stud research is not opened internationally. Soccer is a game of feet. Not just of inches and yards, but of flesh and bone.

Until recently the starting point of the design of any new soccer shoe was based on the low cut, soft leather upper boot with polyurethane or aluminium studs desi후ed in the 1960s. In recent years moulded sole units have evolved, some claiming to increase performance, some to reduce injury risk. However, these claims are not reinforced by data in the scientific literature.

Although player's costumes have changed unrecognisably since early days of the game (Morris,1981), according to McDowell (1994), football boots have undergone surprisingly few design changes in the last seventy years. The evolution of boot development has been a conflict between protection from the climate and injury; against the freedom of limb movement to perform better. Improved fitness of players combined with greater glittering prizes has undoubtedly had a positive spin on boot development but these changes surprisingly appear to be stylistic as the football codes have become more glamorous rather than forged by any desire to play better or decrease the rates of injury. As if by irony it appears from the published literature there have been more injuries caused by boot innovations than appear to be resolved by new designs. This includes the adaptation and incorporation of new synthetic polymers. The incidence of football related injuries are now the focus of much concern. Paradoxically safety changes to soccer footwear are less likely to come from the professionals themselves, as boot sponsorship has become a major source of income. Instead the genuine concern of Soccer Mums, especially in North America, where the game has become so popular with young children, will forge greater safety awareness likely to change the modern game and soccer boot forever.

This research led to shoe design thought to cope with the problems but the number of reported injuries did not decrease. Moreover it seemed, in retrospect, many reported injuries arose as a result of the injury preventing solutions in boot design. Many injuries are attributed to adverse physical conditions at the interface between the soccer shoe and the playing support surface.

The function of the soccer boot provides some means of attachment to the playing surface whilst encasing the foot for protection. No shoe can ever guarantee full protection against injuries, because there exists a conflict between the function of the shoe and the interests of the human body. The maintenance of static balance for a player performing an individual skill demands a significant level of torque. Excess torque or twist passes proximally through the foot pedestal to damage the ankle or knee. During contact, a static foot anchored to the ground negates its ability to dampen down (shock absorb) external forces, such as caused by contact with another player. The ankle and knee then have to absorb the energy of impact, alternatively torque within the short bones of the foot may cause them to fracture. This type of incident was illustrated by recent injury to David Beckham (Manchester United & England). Such great store is placed on individual players of his calibre that in the FIFA World Cup Korea Japan game against Sweden in the openning round, he wore a special supportive sole in his boot designed to give maximum Ironically the custom-made footwear was made by a Swede, called Jorgen Wiklander. It has also become the player's custom to wear a new pair of the now famous silver boots for each game.

The importance of the soccer shoe outsole stud development-injury-biomechanic research relationship in soccer has been stated(Ekstrand and Nigg, 1989;Inklaar, 1994) due to the specific surfaces associated with ball skills. With the techniques of soccer's specific research such as soccer shoes outsole stud function on the Soft ground, Hard ground, Turf ground, Firm ground unreported in Korea, it was the aim of present study to arrange such outsole stud function on a different surface whilst also investigating the effect of using the modern, redesigned soccer sole stud unit.

Ⅱ. Biomechanical Research

Soccer ranks as a high-risk activity when injury is concerned (Lambson, Barnhill & Higgins, 1996). Each season there appears more and more new boot design innovations yet the number of injuries continues unabated. Epidemiological studies indicate adult males are likely to suffer one injury per 167 hours of play; female soccer players are at higher risk with approximately one injury per 147 hours of play (Nilsson, Roaas, 1978; Schmidt-Olsen et al 1985; Sullivan et al 1980). Most injuries are traumatic but there is a high incidence of overuse injuries also reported. (60/40 ratio). Traumatic injuries arise during games more than practice and the risk of injury risk increases with the playing season.

Between 68%-88% of all soccer injuries involve the lower limb (Albert, 1983; Ekstrand, Gillquist, 1983; Engstrom, Johansson, & Tornkvist, 1991; Fried, Lloyd, 1992; Nilsson, Roaas, 1978;Schmidt-Olsen et al, 1985;Schmidt-Olsen et al 1991). The knee and ankle are the most likely to be injured. (Brynhildsen, Ekstrand, & Jeppsson, 1990; Ekstrand, Gillquist, 1983; Engstrom, Johansson, & Tornkvist, 1991; Fried, Lloyd, 1992; McCarroll, Meaney, Sieber, 1984; Schmidt-Olsen et al 1991). Thought to be the most common occupational injury associated with soccer and reported by as many as 60% of soccer players is Anterior Ankle Impingement Syndrome (or Footballer's Ankle). The condition is caused by either; thickening of the tendon and joint capsule caused by stretching with the downward movement of the foot when the ball is kicked; or alternatively, osteophytic damage (bone) to the ankle joint caused by contact with the ball (Tol, Slim, van Soest, & van Dijk, 2002).

Kicking is the most widely studied soccer skill (maximum velocity instep kick on a stationary ball) and it would appear modern soccer boots provide poor protection to the foot and ankle from a career in kicking the ball. The incidence and severity of knee injuries has also been significant among football players. The common factor in Anterior Cruciate Ligament (ACL) injuries is foot fixation, which has been described as leading cause of ankle injuries in sport (D'Ambrosia, 1985; Torg, 1982; Torq, Stilwell, & Rogers, 1996) The exact incidence of injury attributable to footwear in soccer remains unknown. Association between cleat design and injury rate is however reported within the literature (D'Ambrosia, 1985; Torq JS Quedenfeld, & Landau,1974).

Several specific mechanisms of injury have been described that produce ACL tears and many of these do not involve contact with another player. Instead problems appear to occur from torsional forces transmitted to the knee when the player makes a sudden directional change with a planted foot while decelerating.

It is generally accepted high frictional forces between the foot and the playing surface result in fixation and this fixation is a least partially responsible for knee ligament injuries. Traditional soccer boots provide traction with the ground, which is critical to a player's performance, however it is now thought this shoe to surface traction may also contribute to injury. With no traction the player finds difficulty in maintaining balance when turning and twisting or running on wet surfaces. Too much traction permits twisting forces to move proximal on joints above the foot.

Application of forces stressing the knee in a plane other than the normal joint motion results in injury if the force exceeds the elastic capabilities of any of the structures being stressed (Torg, Stilwell, & Rogers, 1996). The axial rotation at the playing surface appears to be affected by the magnitude and nature of impact. By the seventies researchers had discovered an association between cleat design and injury. Higher injuries were recorded in conventional shoes with a traditional seven-cleat pattern. The length of the cleats were " 3/4"" long; and "3/8 " in diameter.It was also found the composition of the cleat was a contributory factor.

Researchers identified different patterns of injuries between shoe sizes and concluded the smaller distances between the position of studs, across the ball of the foot, might account for a higher magnitude of rotation. As a result of these finding the changes to the games rules have resulted and size restrictions and other restrictions on cleats.

According to Levy, Skovron, & Agel (1990) any increase in fixation to the ground increases the risk of injury. Ekstrand & Nigg speculated as much as 60% of all non-contact soccer injuries may be due to excessive shoe surface tension. The conclusion of Bonstingi, Morehouse, & Niehel (1975) was torque developed between playing shoe and surface as a result of a force applied to the leg and an athlete depended on the type and design of the shoe's outer sole, the playing surface, the player weight supported, and the foot stance.

The reduction of rotational force is thought by many to reduce the rate of injury to the knee. Tests on artificial turf indicate the more pliable the cleat the greater the release coefficient, although this alters with changes in surface temperature. The researchers concluded release coefficients both within and among shoe models across a range of turf temperatures. Ironically on artificial turf the researchers found flat-soled basketball shoes performed better than cleated soccer boots did.

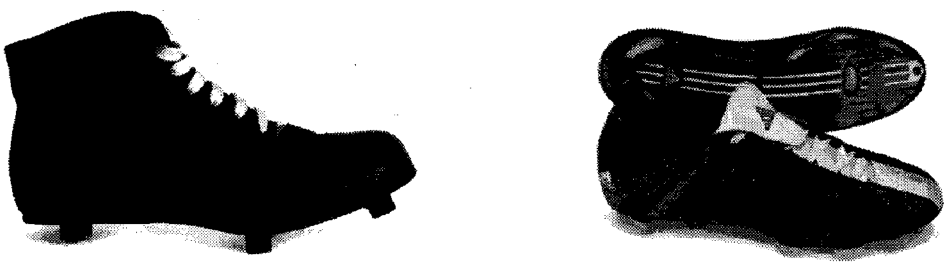
Of particular concern was the introduction of a design that included round spike cleats on the interior portion of the sole with irregular cleats on the outer rim. Although this design enhanced traction, it was reported when worn by athletes it was also associated with a high incidence of serious knee injuries (Majid & Bader 1993). Some players will risk injury to enhance performance, by chosing inadequate boots and cleat designs. Most amateurs remain oblivious to the risks and there have been calls from concerned consumers for manufacturers to indicate clearly on theoir labelling the types of playing surface conditions their shoes are meant for. (Heidt et al, 1996).

The majority of career ending injuries involve the knee, ankles and hips with osteoarthrosis (OA) a serious complication. Approximately 2% of professional players are forced to quite the game due to acute injuries. Despite being low this is higher than many other occupations. However there are a larger number of players forced to quit due to chronic injuries sustained and maintained by playing soccer. Further, Drawer, Fuller, & Waddington (2002) recently reported many retired professional players have admitted to playing games whilst unfit or receiving pain killing treatments for existing injuries with the full knowledge of their employer. Osteoarthritis in a least one of the lower extremity joints is very high and significantly greater than in the general population.

Ⅲ. Athlete Needs and Concept Research in Soccer

The modern soccer shoe provides for foot flexibility during excellerated activity.

Designs contain the accumulated wisdom of shoe makers which includes shoe pitch, to give a pivot action for efficient propulsion when the player accelerates forwards. The necessary stiffness beneath is matched with the need to provide a flat dorsal surface with which to control the ball. Sometimes there is a conflict which usually results in novelties being incorporated. These fads usually have a short life.



A. Soccer shoes in 1830 B. Soccer shoes in 2002

Fig. 1. Soccer Shoes Outsole Comparison

Soccer boots continue to have poor protective capability but manufacturers do try to incorporate innovative designs that are attractive to consumers as well as including design safety features determined by the rules of the game. However the fashion half-life of a sport shoe today is very short and products are as likely to incorporate fads rather than functional components. The three most notable innovations in recent soccer boot design have an Australian flavour, a country not always associated with the world favourite game. Most manufacturers now incorporate Rubberised Kangaroo Technology into their top of the range boots. The soft, yet hardwearing leather uppers are reported as giving the player added grip and ball control. Players put a lot in store concerning being able to feel the ball through the upper of the boot and soccer boots that fit snugly are preferred. Other leather are available and many brand leaders now incorporate synthetics uppers as a viable ulterantive to discerning vegans. The tradition of incorporating kangaroo skins for sports shoes however goes right back to Victorian Times when quality croquet and cricket boots were made from the Antipodean hide. Several years ago Asics developed an innovative cleat designed to help prevent rotational collateral damage to the knee, reported in Australian Rules Footie players. The prototype shoes soon became popular with other football codes including Australian soccer players. The Asics system allowed optimal traction without hindering the player from running freely on hard or artificial surfaces. Similar cleat patterns are now incorporated within contemporary boot design. Australian Craig Johnson (formerly Liverpool FC and Scotland) was convinced by changing the surface contour of the soccer boot, greater ball control would follow. He experimented for many years until his prototype Predator was eventually accepted by Adidas, and now the Adidas Predator TM is in its sixth generation.

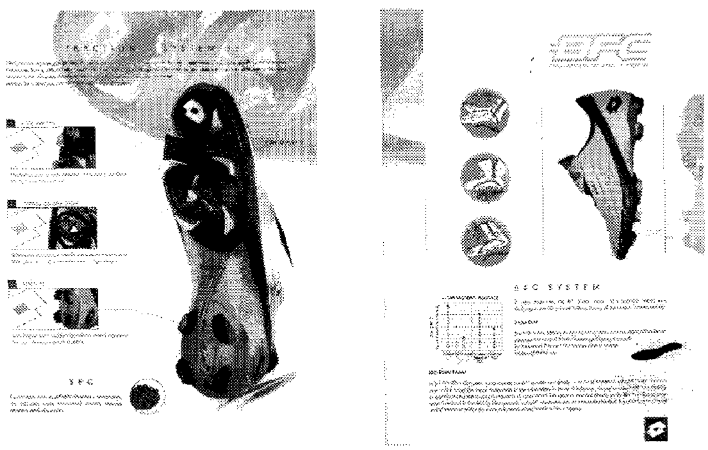


Fig. 2. Biomechanical Foot Control System in soccer shoes

Table. 1 Basic types of shoes wear depending on the type of surfaces play on

	surfaces type	contents	Shoes Outsole	Item
1 S.G.	Soft ground soccer shoes	Generally worn for play on soft ground and usually have six permanent or replaceable studs on the bottom of the shoe.		Men's Predator Mania XTRX Soft Ground
2 F.G.	Film ground soccer shoes	Fim Ground Soccer Shoes are designed for dry and grassy fields. For most players this is the best neral purpose shoe. All of our styles are made with soft, supple uppers for maximum performance. These are the traditional soccer shoes that most kids wear. They have multi-cleats, with anywhere from 12 to 15 studs.		Men's Predator Mania TRX Firm Ground
3 H.G.	Hard ground soccer shoes	Shoes for play on hard ground have about 25 short studs. They are a good choice for day-to-day training, as more studs offer your feet more support and better traction. There are more pressure points to evenly distribute your weight across the bottom of the shoe.		Men's Predator Mania TRX Hard Ground
4 Turf	Turf soccer shoes	These can either have a flat bottom (for indoor use), or hundred' s of little nubs (for outdoor use). The small bevels on the outdoor version help you grip outdoor turf, and offer slightly increased support if the ground is wet.		Men's Predator Mania TRX Turf

The ability to play on different surfaces was recognised early on and hence the sole of the boot needed to offer resistance or ground traction. At first the metal tacks on engineer's boots were used, but Rule 13 meant greater care needed to be taken. Eventually leather cleats (or studs) replaced these. By the twenties Adi Dassler had developed replaceable studs which firmly established his credentials as soccer boot specialist in Germany.

(A) Foot Pressure Testing(NIKE, 2000)

(B) Motion Analysis (UMBRO, 2001)

Fig. 3. biomechanical testing scene in new soccer shoes stud development

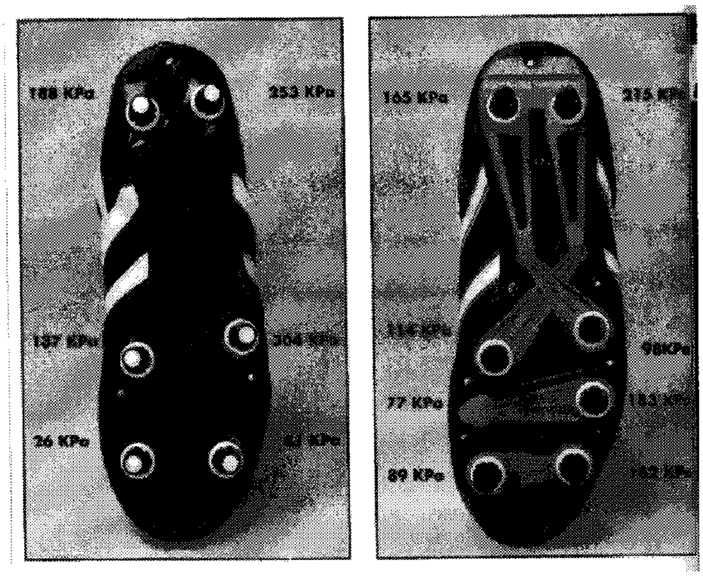
The length of studs was goverend for in 1951 and with the availability of new polymers natural materials were replaced by synthetics. The idea for moulded studs had been tried on hockey boots and when they were transferred to soccer boots a new revolution took place. Today plugs and cleats of variable length are used. Soccer boots should afford confident contact with playing surfaces as well as adapt optimally to all types of surfaces and weather conditions. On hard surfaces, including hard natural turf, cleats of different configuration are recommended. On softer turf or wet ground surfaces shoes with detachable studs with varying length provide the best anchoring to the ground.

On snowy surfaces other configurations are necessary and rubber studs preferred. Icy surfaces again demand a different sole configuration. Traditionally, Bootmen were retained by professional clubs and oversaw the maintenance of the football boots, usually via the apprentices. One of the most famous soccer apprentices and bootboy was Rod Stewart (Bentford FC). Using their previous experiences as players with a command for the game Bootmen advised the young players on the type of boot for the weather conditions. The Boot Room a place where the game strategy was worked out and the most famous Boot Room was at Liverpool FC under the direction of Bill Shankly.

Today tread patterns have changed and now incorporate curved cleats set into circular arrangements. The circular arrangement facilitates better grip in all directions and faster acceleration from the playing surfaces. Greater emphasis is given to the base area across the ball of the supporting foot, which reduces peak pressures on the soles of the feet over a long game. Cleat designs now allow the foot carrying the player's weight to pivot when the player twists or is struck by another player. This helps reduce injury form direct trauma. Further the anti-torque property offered by the circular configuration of compressible teeth (cleats) is thought by the designers to reduce rotational injuries to the knee and ankle. As the game has improved and the demands of professionalism become a primary focus the number and types of injury recorded have increased. These in no short measure have been associated with boot design (Masson & Hess, 1989).

Traditional conical cleats have been cited as the main cause of such injuries and lock into the turf. It was recognised as far back as 1948 that heel cleats was responsible for foot fixation and this contributed to knee damage in soccer players. The principle functions of cleats was to offer resistance next to the ground by holding the foot stable as the body's centre of mass passed over it. One major disadvantage is if the cleat fixed too firmly to the ground then damage to the musculo-tendonous, ligamentous, cartilaginous, or osseous structures of the joints may occur. When the foot was fixed by impact or rotation of the body, these corkscrew forces passed upwards to the knee and were thought to damage the joint and its peripheral attachments. Attempts were made to design a more useful sequence of cleats for heels and forefoot but in the absence of moulded soles this meant few players were aware of them. According to Torq & Quedenfeld, there were two factors, which determined foot fixation and these are the number and the size of the cleats. The authors were able to show in a retrospective study of football injuries, players wearing cleats were less likely to suffer knee injury. The shoes with moulded soles containing fourteen, 3/8 inch cleats. Minimum cleat tip diameter of 1/2 inch and maximum cleat length of 3/8th inch.

In the early days football boots weighed approx. 500 grams when dry and twice as much when wet. When manufacturers were made aware the boot was only in contact with the ball for about 10% of the game, they developed less heavy boots. Lighter footwear meant players were less exhausted and subsequently the overall speed of play increased. This made for a more enjoyable spectator sport. The soccer boot was streamlined with the ankle hugging component reduced to below the malleoli (anklebones). At first this met with concerns about ankle injuries, but this proved ill founded. The traditional soccer boot was now a slipper or soccus. Leather soles were first replaced by moulded rubber, and then injection moulded PVC before eventually nylon and plastic provailed. The new synthetic materials were waterproof, cheap to produce and substantially lighter than leather. The upper of the slipper became thinner improved treatment of leather with synthetic waterproof compounds contributed to the development of the new styles.



(A) 6 studs of soccer shoes (B) 8 studs of soccer shoes

Fig. 4. Pressure distribution data comparison of soccer shoes stud development

The physical properties of kangaroo skin were recognised very early in the 19th century and most quality sports footwear was made from the marsupial's skin. This tradition has quietly continued in soccer shoes and now most quality shoes are now made from medium brown, vintage kangaroo leather. This is a name given to the process of tannage (preparing the leather)

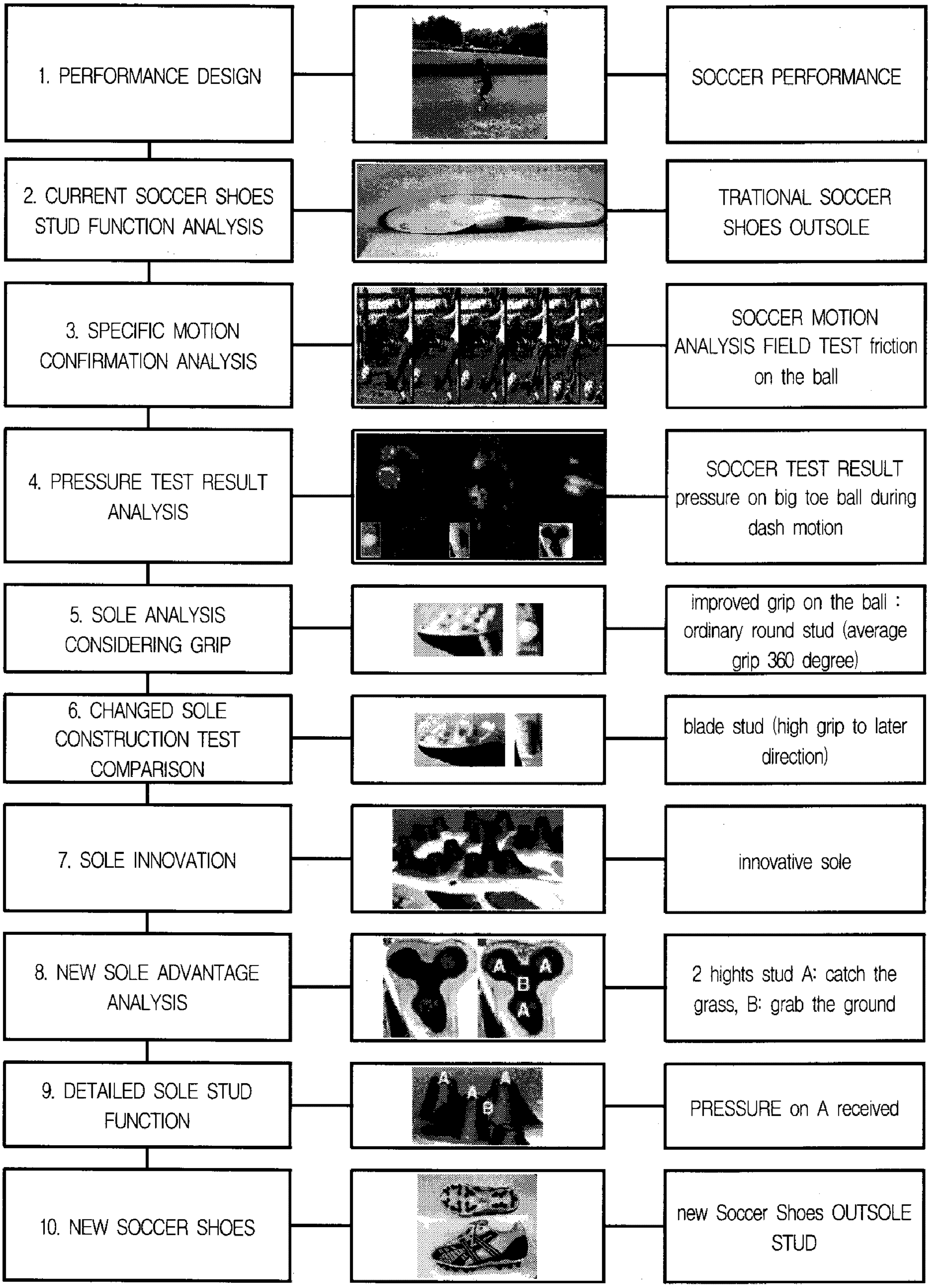


Fig. 5. Shoes sole stud construction design procedures in biomechanical test

and often the leather is dyed to popular dark colours. Kangaroo hide is the toughest and most durable available and been used to produce quality sports shoes for rugby, American football, baseball, basketball, tennis and cycling shoes for over a century. It is lightweight yet very strong and many times stronger than the same thickness of cowhide. Comfortable and supple it requires no break-in period and gives the player a tight fit with optimal feel for the ball. Suitably treated Kangaroo leather is favoured because of its high performance nature. Kangaroo leather has a naturally high strength-to-weight ratio.

Table 2. Soccer Shoes Sole Pressure

	
Umbro XAI	Umbro XAI
	
Sole Pressure	Traditional Sole Pressure

Tanning further enhances the leather's properties by unsticking the fibre bundles thereby allowing them to move independently. Their recent popularity may be explained by "Foot & Mouth " and Mad Cow Disease scares. Whilst recent animal rights activists have brought the use of kangaroo skin to the public's attention by condemning players like David Beckham, who endorse their use reputable firms collect kangaroo hides during the Kangaroo Harvest. Environment Australia - Wildlife Protection (an Australian Federal Government agency whose job it is to regulate and control the harvest and manufacture of all kangaroo leather) regulates this with the ruling that only non-endangered species can be used.

A : Upper B : Outsole Stud

Fig. 6. Soccer Shoes Outsole of David Backham

Today's boots weigh less than 250gms eg Mercurial Vapour(NIKE) - 196 gms. Development of latex foam, meant the soccer shoe could be cushioned at no detriment to overall mass and new lightweight synthetics were stronger and harder wearing than traditional soles. According to Grau (1997) the focus of boot research from the 70s has been primarily directed at anti-pronatory control (preventing the foot from rolling over0. This was combined by using cushioning mechanisms to damped shock to the foot. Later researchers looked at torsion and pressure distribution across the foot. Initially it was wrongly assumed overloading of the weightbearing foot was the primary cause of most injuries.

Footwear performance needs to be addressed by consideration of the shoe-surface interface, rather than isolated properties of either one of these variables. Data regarding the performance of soccer players on natural turf with soccer footwear remain scarce. Only Saggini and Vecchiet(1994)have reported measurements of ground reaction forces from soccer players during straight running on natural turf. Furthermore, the ecological measurement of forces at the shoe-surface interface during soccer specific movement remains absent.

V. Conclusions

The history of soccer is long, the modern game has its origins in the nineteenth century. Started as a rough and tumble game it began to take form in the Private Schools of England. Whilst the final rules of soccer evolved from rugby, the game of football was played in modified engineers boots. Children of the privileged class had their boots made by local bootmakers.

The design of soccer outsole boots remained almost exactly the same for over a century with only minor modification. As rubber, then plastic industries developed, new treatments and synthetic polymers became available these were eagerly incorporated into the footwear. However little real boot innovations resulted. By the late forties it was recognised stud patterns were a potential cause of injury however little change took place until more sophisticated scientific analysis was available in the 1970s. By this time soccer shoes had become fashion attire, instantly recognisable through designer logos, sported by high profile player endorsement and team sponsorships.

Design emphasis remained on performance with injury prevention a secondary consideration. Changes to the rules of the game, new ball technology as well as the introduction of artificial playing surfaces all converged to replace the traditional heavier boot with long studs to a more streamlined soccer slipper with cleats. Emphasis on producing a lightweight sport shoe suitable for kicking a ball has resulted in the conventions of shoe making being combined with twenty first century technology. Despite this, according to published reports from credible sources, the modern soccer shoe provides no more protection to the player than the boot from yesteryear.

An innovative outsole and lug design that replaces conventional studs. Increased surface area between shoe and ground provides superior ground penetration. The surface area is optimized for better traction, comfort, grip, and performance. Soft outsole materials provide surface adaptability and flexibility. When an athlete comes into contact with the ground, it is of utmost importance to achieve appropriate grip during landing. During push off, it is essential to avoid losing propulsion forces because of slippage.

In Korea, soccer research's biomechanical research focused on the ground reaction force analysis , foot pressure analysis and 3 dimentional motion analysis of foot motion, lacked biomechanical testing, evaluation method, research information and analysis of soccer shoes compared with traditional stud and new style's stud. In future, Grip and friction force research of an outsole are important features when considering new designs for soccer shoes in korea's researchers.

References

Bonstingi RW, Morehouse CA, Niehel BW.(1975). Torques developed by different types of shoes on various playing surfaces Med Sci Sports 7. pp.127-131.

Brynhildsen J, Ekstrand J Jeppsson A.(1990). Previous injuries and persisting symptoms in female soccer players Int Journal Spots Med 11. pp.489-492.

Chapman A.(2002)..and boots earn soccer stars a lacing The Sunday Mail (Brisbane , Australia) 01-20-2002. p.34.

D'Ambrosia R.D.(1985).Orthotic devices in running shoes Clinical Sports Medicine 4. pp.611-618.

Denvir C.(1979).The sports shoe In Baynes K & Baynes K (eds) The shoe show British shoes since 1790 England: The Crafts Council. pp.90-93

Ekstrand J, Gillquist J.(1983). Soccer inuries and their mechanisms: A prospective study Med Sci Sports Exerc 15. pp.267-270.

Ekstrand J, Nigg B.(1989). Surface related injuries in soccer Sports Medicine 8 pp.56-62.

Fried T, Lloyd G.J.(1992).An overview of common soccer injuries: Management and prevention Sports Med 74. pp.269-275.

Grau S.(1997). Quo vadis sport-shoes? Wish and reality of preventing injuries through sport shoes Third Symposium on Footwear Biomechanics, Tokyo 1997 International Society of Biomechanics

Heidt R.S. et al.(1996). Differences in friction and torsional resistance in athletic shoe turf surface interfaces Am Journal of Sports Medicine 24:6. pp.834-842.

Heidt R.S. Sweeterman L.S., Carlonas RL, Traub JA, X F.(2000). Avoidance of soccer injuries with preseason conditioning American Journal of Sports Medicine 28:5. pp.659-662.

Lambson R. Barnhill B.S., Higgins R.W.(1996). Football cleat design and its effects on anterior cruciate ligament injuries: A three year prospective study American Journal of Sports Medicine 24:2. pp.155-157.

Lees A., Nolan L.(1998) The biomechanics of soccer : a review Journal of Sports Sciences 16:3. pp. 211-234.

Levy I.M., Skovron M.L, Agel J.(1990). Living with artificial grass: A knowledge update Part 1: Basic science American Journal Sports Med 18. pp.406-412.

Lineker G., Hey S.(1998). Gary Lineker's golden boots: The world greatest strikers 1930-1998 London: Hodder & Stoughton

Luhtanen P.(2002). Soccer: Biomechanics of soccer equipment Faculty of University of Edinburgh

Lambson R., Barnhill B.S., Higgins R.W.(1996). Football cleat design and its effects on anterior cruciate ligament injuries: A three year prospective study American Journal of Sports Medicine 24:2 pp.155-157.

Majid F., Bader D.L.(1993). A biomechanical analysis of the plantar surface of soccer shoes Proceedings Instn Mechanical Engineers 207:2 pp.93-101.

Marples M.(1954) A history of football London: Secker & Warburg

Martin D.R.(1997). How to steer patients toward the right sport shoe The Physician and Sportmedicine 25:9 pp.138-140

Masson M., Hess H.(1989). Typical soccer injuries: Their effects on the design of athletic shoe In Segesser B & Pforringer W(eds) The shoe in sport London: Wolf Publications. pp.89-95.

McDowell C.(1994). Shoes: Fashion and fantasy London: Thames & Hudson. pp.172-173.

Minerd J.(1999). Shoes make great strides The Futurist 33:5. pp.46-47.

Morgan B.E., Oberlander M.A.(2001). An examination of injuries in major league soccer: The inagural season American Journal of Sports Medicine July/Aug 29: 4. pp.426-430.

Nilsson S, Roaas A.(1978). Soccer injuries in adolescents, American Journal Sports 6 pp.358-361.

Schmidt-Olsen et al.(1991). Injuries among young soccer players American Journal of Sports Medicine 19. pp.273-275.

Soderman K., Adolphson J., Lorentzon R., Alfredson H.(2001). Injuries in adolescent female players in European football: a prospective study over one outdoor soccer season Scandanavian Journal Medical Science Sports 11:5 pp.299-304.

Tol J.L., Slim E., van Soest A.J., van Dijk N.(2002). The relationship of the kicking action in soccer and anterior ankle impingement syndrome: A biomechanical analysis American Journal of Sports Medicine Jan /Feb 30:1. pp.45-50.

Torg J.S.(1982). Athletic footwear and orthotic appliances Clin Sports Med pp.157-175.

Torg J.S., Quedenfeld T.(2000). Effect of shoe type and cleat length on incidence and severity of knee injuries among high school football players. The Research Quarterly 42:2. pp.203-211.

Torq J.S., Quedenfeld T.C., Landau B.S.(1974). The shoe surface interface and its relationship to football knee injuries, Journal Sport Medicine, 2. pp.261-269.

Torq J.S., Stilwell G., Rogers K.(1996). The effect of ambient temperture on the shoe surface interface release coefficient, American Journal of Sports Medicine 24:1. pp.79-80.