

Institution: London South Bank University		
Unit of Assessment: 24 – Sport and Exercise Sciences, Leisure and Tourism		
Title of case study: Changing coaching practice in German track and field athletics using a novel diagnostic testing and training device (TEMULAB®) to reduce Achilles tendon injuries.		
Period when the underpinning research was undertaken: 2016 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Kiros Karamanidis Dr. Gaspar Epro	Professor Senior Lecturer	2016 – present 2016 – present
Period when the claimed impact occurred: 2016 - 2020		
Is this case study continued from a case study submitted in 2014? N		
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>Over their career professional athletes have an estimated 24% chance of developing an Achilles tendon (AT) injury, which can cause prolonged absence from training and competition. Professor Karamanidis and colleagues have developed a mobile diagnostic testing and training device called TEMULAB® that provides instant feedback to identify an athlete's susceptibility to AT overuse injury; this enables coaches to immediately respond and adapt the training intensity. Since 2016, TEMULAB® has been used regularly by 15 German Athletics Association (DLV) coaches and 67 of their elite athletes at 9 Olympic training centres and the largest track and field club in Germany. Diagnosing AT strength helps coaches to individualise training intensity and in doing so, has reduced the prevalence of AT injury as much as 75% in some coaches' squads. DLV coaches credit TEMULAB® with changing their coaching practice, giving them a deeper understanding of the periodic and divergent fluctuations of muscle and tendon capacities of their athletes. TEMULAB® has also been adopted in private medical practice to prevent and rehabilitate AT injuries in amateur athletes.</p>		
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>Context. The Achilles tendon is the strongest and largest tendon in the body, but also the most vulnerable with the lowest rupture threshold. It is the most commonly injured tendon and athletes are ten-times more likely to damage it than the general population, with a lifetime incidence rate of approximately 24%. In runners, this rises to 40%. The consequence of AT injury often leads to absence from major competitions and in some cases the athlete will never return to pre-injury performance status.</p> <p>A body of empirical research on muscle-tendon unit biomechanics conducted by Professor Karamanidis with colleagues from the German Sport University Cologne, found that the AT requires high load exercise in order to increase its tensile strength (e.g. increased stiffness). That is to say that, unlike its adjoining calf muscle (Triceps Surae), which responds to most sub-maximal intensities of exercise to improve its strength, the AT preferentially adapts to high intensity exercise. This means that typical training regimes to build Triceps Surae muscle-tendon unit strength, or aide recovery from injury, are often insufficient for the AT. From 2016, Professor Karamanidis has conducted further research exploring muscle-tendon unit biomechanics in the ageing process [R1, R2, R3] and prevalence to tendon injury in athletes [R1, R4, R5, R6]. He specifically hypothesised in the athletic research that non-uniform adaptations in Triceps Surae strength and AT stiffness throughout a training year would temporarily place the athlete at a greater risk of AT overuse injury. To be able to investigate this muscle-tendon imbalance phenomena in athletes, and importantly outside of his laboratory, Professor Karamanidis and colleagues developed a mobile diagnostic testing and training device called TEMULAB® (Figure 1). It incorporates synchronised dynamometry, ultrasonography and electromyography to instantaneously measure the mechanical properties of both structures in the Triceps Surae muscle-tendon unit and can be used to guide training based on the outcome. Funded projects for development and long-term monitoring of DLV athletes has revealed a number of key findings in this area of research.</p>		

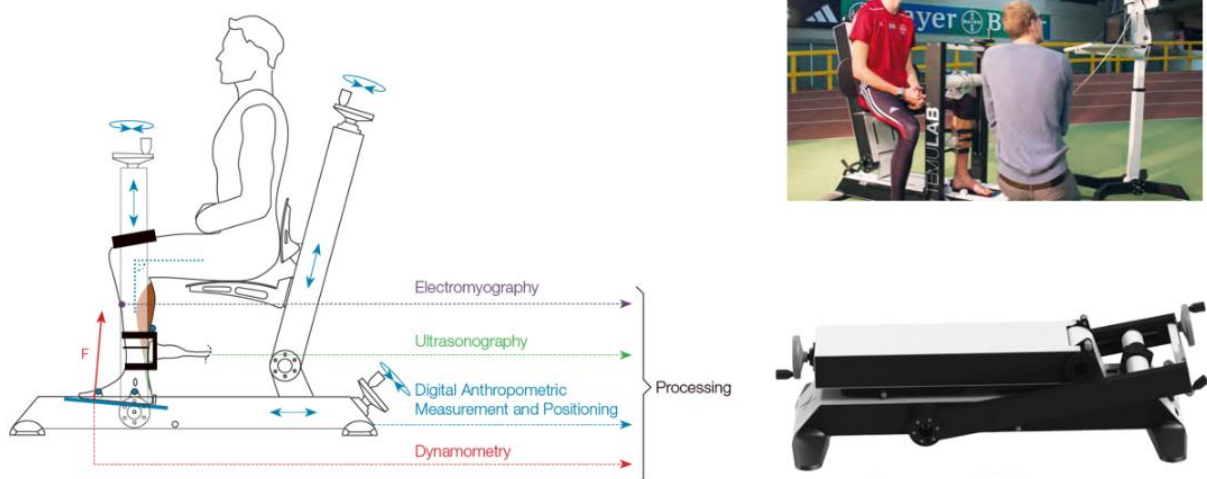


Figure 1. TEMULAB® is a portable diagnostic monitoring and training device that provides instantaneous feedback on Triceps Surae muscle strength and Achilles tendon stiffness.

Key findings: The first key finding from Professor Karamanidis's research since 2016 was evidence that the mechanical properties of AT are age-sensitive [R1, R2, R3]. In the first study, middle-aged runners showed a significantly lower AT stiffness following a half-marathon compared to younger runners. This finding implies a higher susceptibility to overuse AT injury in older adults and importantly points to the need for individualised load-managed testing and training of the AT. A second key finding revealed that AT tendinopathy [R6] and rupture with subsequent reconstruction [R4] causes a substantial Triceps Surae muscle-tendon imbalance, which, in the latter case, was irreversible even with an individualised load-managed training regime [R4]. The implication here is that every effort is needed to prevent AT injury in sport otherwise there is a risk that the athlete may not return to pre-injury performance status. Indeed, after a year of regular (every 2-4 weeks) diagnostic monitoring of athletes ($n=18$), TEMULAB® was shown to be effective in reducing the incidence of AT injury (third key finding). In this cohort of athletes no AT injuries were incurred and individualised load-managed training prescribed by the device, after every test, ensured a balance in the adaptation of Triceps Surae strength and AT stiffness throughout the athletes' season [R4,R5].

A fourth key finding from the long-term monitoring programme ($n=67$; 2016-20) was that the average athlete demonstrates large fluctuations in the uniformity of Triceps Surae strength and AT stiffness [R6]. This was shown to be independent of training period (e.g., pre-season vs competition) and largely due to rapidly changing muscle strength. At these time points, there is an increased tendon strain and therefore a higher susceptibility for tendon overuse injury, which coaches, scientists and clinicians at the various Olympic training centres around Germany are now aware of and actively monitoring and adjusting their athletes' training regimes to ensure a uniformity in Triceps Surae strength and AT stiffness.

3. References to the research (indicative maximum of six references)

- [R1] Ackermans TMA, Epro E, McCrum C, Oberländer KD, Suhr F, Drost MR, Meijer K, Karamanidis K. (2016). Aging and the effects of a half marathon on Achilles tendon force-elongation relationship. *European Journal of Applied Physiology*. 116: 2281-2292. DOI: <https://doi.org/10.1007/s00421-016-3482-z>
- [R2] Epro G, Mierau A, Doerner J, Luetkens J, Scheef L, Kukuk G, Boecker H, Maganaris C, Brüggeman GP, Karamanidis K. (2017). The Achilles tendon is mechanosensitive in older adults: adaptations following 14 weeks versus 1.5 years of cyclic strain exercise. *Journal of Experimental Biology*. 220(Pt 6):1008-1018. DOI: <https://doi.org/10.1242/jeb.146407>
- [R3] McCrum C., Leow P., Epro G., König M., Meijer K. & Karamanidis K. (2018). Alterations in leg extensor muscle-tendon unit biomechanical properties with ageing and mechanical loading. *Frontiers in Physiology*, 9:150. DOI: <https://doi.org/10.3389/fphys.2018.00150>

- [R4] König, M, Epro, G, McCrum, C, Bädorf, M, Schade, F and Karamanidis, K (2017). The effect of habitual athletics training on muscle and tendon adaptation in young and older elite athletes. *2017 BASES Biomechanics Interest Group Meeting, Portsmouth*. Portsmouth 19 – 19 Apr 2017
- [R5] Epro G, Hunter S, König M, Schade F & Karamanidis K (2019). Evidence of a Uniform Muscle-Tendon Unit Adaptation in Healthy Elite Track and Field Jumpers: A Cross Sectional Investigation. *Frontiers in Physiology*. 10:574. DOI: <https://doi.org/10.3389/fphys.2019.00574>
- [R6] Karamanidis K, Epro G (2020). Monitoring muscle-tendon adaptation over several years of athletic training and competition in elite track and field jumpers. *Frontiers in Physiology*. 11:607544. DOI: <https://doi.org/10.3389/fphys.2020.607544>

Evidence of the quality of this research: Articles R3, R5 and R6 are published in *Frontiers in Physiology*, which is the 2nd most cited Physiology Journal worldwide. Professor Karamanidis presented the data published in R6 in an invited keynote at the 2019 European Congress of Sports Science. R3 was nominated for the 2017 Journal of Experimental Biology outstanding paper award (runner-up). R4 received the BASES young investigator award (Dr. König). The data from R5 was presented by Dr. Epro at the 2019 FIFA Isokinetic Medical Group conference at Wembley stadium. R2 and R6 are submitted as outputs for REF2021 in UoA 24.

Grants: Research and development of TEMULAB® was supported by three grants (2016–2022) from Olympiastützpunkt (OSP: Olympic training centres) Rhineland and Hessen worth a total of €216k. Long-term monitoring of DLV athletes was supported by the Federal Institute of Sport Science of Germany (2016-2020) worth €115k. A consultancy contract for £312k (2019-2022) is in place between Lanserhof at the Arts Club (London) and LSBU for day-to-day running of diagnostic facilities. Professor Karamanidis is the named Principal Investigator in all of these grants/projects.

4. Details of the impact (indicative maximum 750 words)

TEMULAB® has been used for diagnostic monitoring and individualised load-managed training within Germany's 2nd largest sports organisation - the German Athletics Association (DLV), which has 800,000 members. The use of TEMULAB® has resulted in a change in practice in how DLV coaches prepare their athletes for major competition [S1, S2, S3, S4, S5]. This has benefitted athletes directly [S6] with some coaches reporting as much as a 75% reduction in Achilles tendon (AT) injuries since 2016 [S5]. TEMULAB® has also been adopted in private medical practice [S7] to prevent and rehabilitate amateur sporting injuries.

Altering Coaching Practice at DLV and reducing tendon injuries: The results from short [R4] and long-term [R5, R6] athlete monitoring have changed the way in which DLV coaches individualise and periodise their athletes' training schedules. Hans-Jörg Thomaskamp is the DLV national head coach for men's high jump and sports director of all track and field coaches at the largest track and field club in Germany: TSV Bayer 04 Leverkusen. He has included TEMULAB® diagnostic monitoring within the training schedules of all 20 DLV athletes located at TSV and has recently facilitated the funding of a re-development of the device to allow for training-specific monitoring of Triceps Surae muscle-tendon unit strength. Thomaskamp individualises his athletes' training regimes based on the uniformity of this regular monitoring and this all stems from the transfer of Professor Karamanidis's knowledge and expertise into DLV practice. Thomaskamp states: "*the inclusion of TEMULAB® has clearly aided to prevent, reduce and overcome tendinous injuries throughout the season, hence allowing us to keep the athlete preparation and competition readiness at the highest professional level*" [S1].

This testimony is supported by the results of an online survey [S5] completed by six DLV jump coaches (including Thomaskamp) who between them coach 38 athletes (of the 67 regularly monitored between 2016-20). The survey revealed that 4 out of 6 coaches have witnessed a decline in AT injuries since regular monitoring of their athletes began, with some claiming as high as a 75% reduction. The coaches assert that this dramatic decline is due to TEMULAB®, which has allowed them to respond quickly to athletes' individual training needs as they change over the season. 5 out of 6 coaches agreed that TEMULAB® has changed the way they prepare their athletes for competition and agree/strongly agree that TEMULAB® reduces the risk of AT injury.

Mateusz Przybylko, a high jumper under Thomaskamp's supervision, acknowledges that TEMULAB® monitoring has contributed to his success on the field. Since Thomaskamp introduced TEMULAB® into his training schedule, his training has been individualised to adapt to fluctuations in the uniformity of his Triceps Surae strength and AT stiffness [S6]. During this period, his classifications at major championships have steadily improved from 28th at the Olympic games (2016), to 5th at the World Championships (2017), and then to 3rd and 1st at the 2018 World Indoor Championships and European Championships, respectively [S8]. He states: *“the regular performance and medical diagnostics with the TEMULAB® have reassured me that my preparation and regeneration are running in harmony and that I do not overload the tendon. The results have helped directly my coach to modify our training plans. TEMULAB® has been an important part for my steady progression and I have definitely profited from regular monitoring as I have been injury-free, and my results have been progressive at major competitions”* [S6].

In excess of 15 coaches under Thomaskamp's directorship have adopted regular TEMULAB® diagnostic monitoring of their athletes and between 2016 and 2020, 67 professional DLV athletes have had TEMULAB® included as part of their training regime. The athletes appreciate the monitoring, are engaged with the device and understand the context in which it is used [S2, S4, S5, S6]. Pablo Oehl is a TSV Bayer 04 Leverkusen coach and states: *“Over the time my athletes have gotten used to regular measurements and get excited about knowing what their current conditioning status is. They understand that measuring their tendon stiffness regularly means that loads can be better controlled, tolerated more and allows for higher quality intensive training”* [S4].

Enabling regular monitoring of athletes across Germany: The use of TEMULAB® has benefitted coaches more widely across Germany. TEMULAB® was first introduced at OSP Rhineland, which led to a number of other German Olympic Training Centres affiliated with the facility to experiment with monitoring of their athletes. Dr. Falk Schade, sports physician at OSP Rhineland in charge of diagnostics, and in this context responsible for the transfer of scientific knowledge to the field states: *“the device has been used across various national associations including [DLV], [Football], [Hockey] and the [Bobsleigh] teams. We have received positive feedback and gratitude from the coaches who feel more informed about how their training is affecting their athletes and how to react in cases when an early muscle-tendon imbalance is detected”* [S2]. TEMULAB® is now operational at OSP Rhineland, Hessen, Frankfurt and Berlin with more than 150 athletes of varying disciplines monitored to some degree to prevent tendon injury. In addition, a national (TEMULAB®) database – joint funded by OSP Rhineland and Hessen (led by Professor Karamanidis) – now means that geographical location is no longer an issue for athletes engaged within the monitoring programme as their diagnostic history and testing protocols are readily available across all centres via cloud storage. Dr. Luis Mendoza, training scientist at OSP Hessen states: *“this initiative has been a tremendous success and allowed for more rigorous monitoring of the athletes. I am convinced of the benefit of TEMULAB® for personalised training and injury prevention”* [S3].

Making TEMULAB® available for amateur athletes: Michael Scharf, Head of the OSP Rhineland training centre until 2019 referred to TEMULAB® as *“a quantum leap for the prevention and therapy of Achilles tendon injuries”* [S9]. This professional opinion is supported by Dr Sebastian Kunz, orthopaedic surgeon who has used TEMULAB® in the treatment of both professional and amateur athletes. He said: *“To have a device that measures the mechanical properties of both muscle and tendon structures, and provides instant feedback to the clinician, is a highly sought-after commodity for clinical decision making. I am not aware of any other device like this”* [S7].

In his clinic Dr Kunz consults many so-called ‘middle-aged weekend warrior/runners’ who can have a reported lifetime incidence rate for AT injury as high as 40%. On this basis, Dr Kunz has installed TEMULAB® at Lanserhof at the Arts Club in London, his private medical practice [S8]. Professor Karamanidis and his team manage the Biomechanical diagnostic suites, overseeing TEMULAB® implementation within members' prevention and treatment programmes. *“Our members expect the highest level of healthcare, and thanks to Professor Karamanidis, we are in position to offer a service that is currently only available to elite athletic populations”* states Dr.

Kunz, who goes on to say: “I expect the number of AT injuries that I will examine over the coming years will reduce” [S7]. TEMULAB was installed in clinic at the end of 2019, but the service has been affected due to the COVID-19 pandemic.

5. Sources to corroborate the impact (indicative maximum of 10 references)

- [S1] Testimonial from TSV Bayer 04 Leverkusen (Hans-Jörg Thomaskamp, Sports Director)
- [S2] Testimonial from OSP Rhineland (Dr. Falk Schade, Sports Physician)
- [S3] Testimonial from OSP Hessen (Dr. Luis Mendoza, Sports Physician)
- [S4] Testimonial from TSV Bayer 04 Leverkusen (Pablo Oehl, Coach)
- [S5] DLV survey (jump coaches): <https://www.surveymonkey.co.uk/r/K53XVB9>
- [S6] Testimonial from DLV (Mateusz Przybylko, athlete)
- [S7] Testimonial from Lanserhof at the Arts Club, London (Dr. Sebastian Kunz; Medical Director and Orthopaedic Surgeon)
- [S8] <https://worldathletics.org/athletes/germany/mateusz-przybylko-14360276>
- [S9] 25 years of High Performance Fascination (2015, Official publication from Olympiastützpunkt Rhineland).