Conceptual Design of a Massaging Device to Mitigate Exercise Associated Calf Muscle Cramps

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Abstract.
Exercise-associated muscle-cramping (EAMC) is a-common-condition, experienced by recreational and competitive-athletes, which can potentially-endanger their-health, as-well-as professional-career. This paper reports the-synopsis of a-conceptual-design, simulation, and analysis of a-massaging-device to-mitigate paraphysiologic-EAMC, in-the-calf-area. Document-analysis was utilized as one of the-study-instruments (including published-research on the-concepts of cramps and their-treatments; selected-relevant International-patents; the-use of anthropometric-data in product-design; prior-art on massaging-devices, and selected-devices, currently available at the-market, with their-respective-limitations). The-study applied fundamental-Engineering-principles of *product* design, and was-carried-out in-compliance with ISO7250: 1996 (Basic-human-body-measurements for technological-design). The-best-ranked-design (out of the 3 design-alternatives, made) was chosen, *via* Engineering-Design Weighted-Decision-Matrix, and confirmed by the 'Drop and Re-vote' (D & R) method. 2D-drawings, of the-best-design-alternative, were created by computer-aided-design (CAD) AutoCAD-software, while 50^{th} percentile, adult-male was selected, as a design-target. Relevant-leg and hand-dimensions (one-dimensional measurements), were obtained from published-anthropometric-data-tables. Simulation of Stress-Analysis/Single-Point Static-Analysis (to-detect and eliminate rigid-body-modes; and separate stresses across contact-surfaces) was done by Autodesk Inventor-Version: 2016 (Build 200138000, 138). Conceptual-design of the-massaging-device was optimized according-to results of simulations, calculations, and fundamental engineering-product design principles. The-study also revealed that the-patho-physiology, causing EAMC, is most-likely multi factorial and complex. Overall, the-results of this-concise-study are rather-positive, providing a-good starting-point for advanced-exploration on the-same. Further-improvements and trials, however, are necessary. The-study, hence, recommended: (i) Further-studies, to-optimize the-dimensions of the-device, to-accommodate different-shapes of calf-muscles; (ii) More-advanced-methods, such-as PuCC; AHP, and TRIZ should be considered in-selection of the-best-design-alternative; (iii) Comprehensive-materials-selection should be detailed *via* Ashby-charts; (iv) To-carry-out a-detail-design; (v) To-fabricate a-prototype; (vi) To-conduct additional-tests (e.g., FEA/FEM) and explorative-use-ability-trials, in-collaboration-with the-department of Medical-Engineering, School of Medicine, MU; and (vii) To-analyze the-marketing-aspect of the-final-device. The-device is potentially-beneficial to sports-health-care-providers, coaches, and athletes; moreover, it could be included into-First-Aid Sport-kit (subject-to satisfactory-trails).
Keywords: EAMC, spasm, athlete, sports, theories.
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1. Introduction.

1.1. Spasms, Cramps, and their-manifestations and effects.

A-muscle-spasm is an-involuntary-spasmodic-contraction, occurring suddenly (with *no* warning), of a-skeletal-muscle, muscle-part, or several-muscles, which are usually-acting-together (Kargus, 2009). A-sustained-muscle-spasm is referred-to as a-muscle-cramp. Cramps are affiliated-to several-muscles, but usually-occur to the-muscles of the-calf, quadriceps, and hamstrings (Jahic & Begic, 2018; BMJ, 2014; Young, 2006). According-to Miller & Layzer (2005), cramps usually-occur in one-muscle, or part of a-muscle, at a-time.

Muscle-spasm can easily-bring even highly-fit-athlete to their-knees, especially if the-muscle-spasm or cramp, occurs during the-active-state (e.g., while-running or performing other-physical activities).These-muscle-spasms, occurring during such-activities are known as Exercise-Associated Muscle-Cramps (EAMC), which is the-subject of this-study.

Schwellnus and his-colleagues provided a-definition of EAMC (Schwellnus *et al.,* 1997), as: "Skeletal muscle cramps that occur during, or shortly-following exercise, in healthy individuals, with no underlying metabolic, neurological, or endocrine pathology". This-definition is adopted by the-current-study.

EAMC leads-to pain and muscular-skeletal-dysfunction that could-induce a-decrease in-performance (Braulick *et al.,* 2013), and could also-lead-to muscle-damage (Edouard, 2014). Clinically, EAMC may-be recognized by acute-pain, stiffness, visible-bulging or knotting of the-affected-muscle, palpable-contraction, and possible-soreness, that can last from few-minutes to several-days (Maquirriain & Merello, 2007; Miller & Layzer, 2005). While EAMC can-be-isolated, athletes often-complain of EAMC-symptoms up-to 8 hours after-exercise. This post-exercise-period of increased-susceptibility to EAMC has been termed the cramp- prone-state (Miller & Knight, 2007).

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Although some-EAMC do manifest only in-mild-discomfort and do not appear to-affect athletic performance (Schwellnus *et al.,* 2007; Maughan, 1986), other-times, EAMC are extremely-painful and can be completely-debilitating (Miller et al., 2010; Brubaker et al., 1985; Moss, 1923), leading-to muscle-injury, and temporarily-loss of mobility, and, hence, can potentially-damage, or even, ruin the-carrier of a-sport man or a-woman.

1.2. Statistics/prevalence of EAMC.

EAMC is common-among-athletes, participating in-long-distance-endurance-events, such-as tri-athlon and marathon, or ultra-marathon distance-running, and it-is documented in many-other-sports, including: basketball, soccer, American-football, tennis, cricket, and cycling (Schwellnus *et al.,* 2008; Kantarowski *et al.,* 1990). The-prevalence of EAMC has been reported for: tri-athletes at 67% (Kantarowski *et al.,* 1990); marathon-runners - between 30% and 50% (Kantarowski *et al.,* 1990); rugby-players - 52% (Summers *et al.,* 2013; Schwellnus *et al.,* 2008); and cyclists - 60% (Schwellnus *et al.,* 2008).

EAMC-susceptibility varies-widely, among individuals; some routinely-develop EAMC, while others, despite-being similarly-matched for conditioning, duration, and intensity, demonstrate cramp-resistance (Shang *et al.,* 2011; Schwellnus *et al.,* 2011). In-the-same-spirit, Miller & Knight (2009) reported that cramp-susceptibility is correlated-with an-individual-cramp threshold-frequency (CTF), defined as the- minimum electrical-stimulation, required to-evoke a-muscle-cramp.

1.3. Classification.

Controversy persists regarding the-classification of muscular-cramps. Parisi *et al.* (2003) described a-patho genesis-based-classification for this-muscular-condition, establishing three-different-types of cramps: (i) paraphysiologic; (ii) idiopathic; and (iii) symptomatic.

Paraphysiologic-cramps develop in-healthy-people and are linked-to certain-circumstances and conditions, such-as exercise or pregnancy. In-idiopathic-cramps, the-muscular-problem is the-main symptom of a-general-disease; these can-be sporadic, are sometimes inherited, and usually are not associated with cognitive, pyramidal, cerebellar, or sensory-abnormalities. A-central, neuronal-origin, at the moto-neuron-level has generally been hypothesized for these-cases. Symptomatic-cramps are manifestations of an-underlying-disease. The-scope of this-study is limited to paraphysiologic-cramps.

Besides, there are two-distinct and dissimilar general-categories of EAMCs (when there is no other underlying-pathology or abnormal-condition-present): (i) First, skeletal-muscle overload and fatigue, from overuse or insufficient-conditioning can prompt muscle-cramping-locally in the-overworked muscle-fibers (Jung *et al.,* 2005; Bentley, 1996); and (ii) Large-sweat-losses commonly-occurred in exercising-athletes (Stofan *et al.,* 2005; Bergeron 2003, 1996). Extensive-sweating and a-consequent significant-whole-body exchangeable-sodium-deficit can lead-to more-widespread muscle-cramping, even when there is minimal or no muscle-overload and fatigue (Stofan *et al.,* 2005; Bergeron, 2003, 1996). This-latter-type of muscle cramping has-been-referred-to as exertional-heat-cramps (Weller *et al.,* 1998); such-term causes some confusion (as cramps often do occur in-cool-environments, and even indoors, although considerable sweating still is present).

The-information, presented here supports the-contention that there are two-primary-categories of EAMC:

(1) Those related-to muscle-overload and fatigue (Buono *et al.,* 2007; Cleary *et al.,* 2007; Schwellnus, 2007, 1997); and

(2) Those skeletal-muscle-cramps, associated-with a sweat-induced-sodium deficit (exertional heat-cramps).

The-current-study assumes that both-courses could be contributing to EAMC.

Lastly, though controversial, an-important-differentiation, in-determining the-cause of EAMC, may-be the-number and location of muscles, affected. EAMC typically-occur in-single, multi-joint-muscles (e.g., triceps surae, quadriceps, hamstrings), when contracting in a-shortened-state (Schwellnus *et al.,* 2007), whereas generalized-EAMC occur in-multiple, usually-bilateral-muscles.

Calf-muscle (the-focus of this-study) is a-bilateral-muscle. **Figure 1** shows the-anatomical- position and depiction of the-calf-muscle, which is the-focus of this-research.

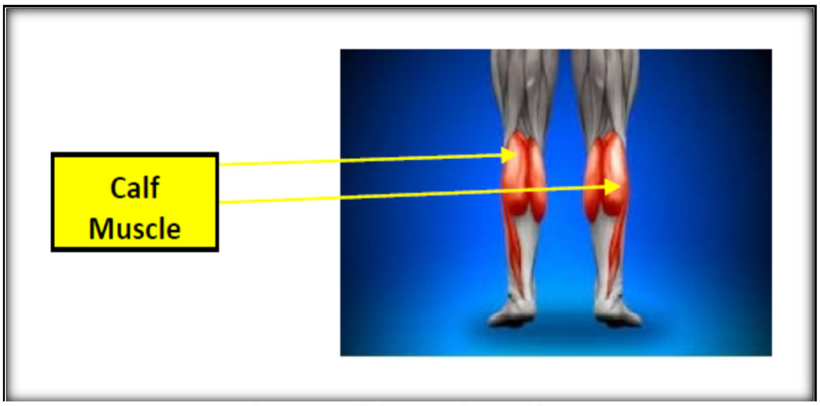

Figure 1: Calf-muscle-position.

1.4. EAMC: Causes and relevant-theories.

EAMC was first-described in the-early-1900s in-association-with physical-work, done in-hot-humid environments (see Edsall, 1908; and Talbot, 1935). The-very-first-hypotheses for the-aetiology of EAMC were proposed over 80 years-ago, when the-condition was-thought to-be-related-to abnormal-serum electrolyte-concentrations, dehydration, or environmental-stress (see Talbot, 1935; Ladell, 1949; Schwellnus *et al.,* 1997). A-new-hypothesis, proposed in the-late 1990s, suggested that muscle-fatigue, and therefore altered-neuro-muscular-control, was the-primary-factor, associated-with developing EAMC (Schwellnus *et al.,* 1997). Cramping has-been-reported to-occur most-commonly in the-later-stages of an endurance event, when fatigue would be a-factor (Manjra, 1991). EAMC are more-likely to-occur when the muscle is contracting in an already-shortened-position (Schwellnus *et al.,* 1997; Ruff, 1996). Shortened muscle is more-prone-to cramping, may explain why calf-muscle-cramps are prevalent in-swimmers, because in most-swimming-races a-swimmer must-swim-with pointed-toes, that require the-calf-muscle to remain somewhat-contracted (Schwellnus *et al.,* 2007; Bentley, 1996).

Different-theories for the-aetiology of EAMC are highlighted (see for details Eichner, 2007; Sulzer *et al.,* 2005; Jung *et al.,* 2005; Schwellnus *et al.,* 2004; Bergeron, 2003; Schwellnus *et al.,* 1997; Armstrong & Maresh, 1993; Hutton & Nelson, 1986; Maughan, 1986; Nelson & Hutton, 1986; Ladell, 1949; McCance, 1936 a, b; Talbot, 1935; Derrick, 1934; Oswald, 1925; Edsall, 1908) as-follows:

Serum-electrolyte-theory

This-theory suggests that EAMC is related to the-decreased-concentration of serum-electrolytes (sodium, potassium, magnesium, chloride, and calcium), resulting-from profuse-sweating or overconsumption of water (Sulzer *et al.,* 2005; Schwellnus *et al.,* 2004; Schwellnus *et al.,* 1997; Armstrong & Maresh, 1993; Maughan, 1986; Ladell, 1949; McCance, 1936 a, b; Derrick, 1934; Oswald, 1925; and Edsall, 1908). On-the-other-hand, several-studies have shown no relationship between serum-electrolyte-abnormalities and EAMC in marathon-runners or tri-athletes (see Drew, 2006; Sulzer *et al.,* 2005; Schwellnus *et al.,* 2004; and Maughan, 1986). The-findings have led-to suggestions that increased-sweat-concentration ('salty- sweating') resulting-in sodium-depletion, rather than changes in-serum-electrolyte-concentrations, is the mechanism for EAMC (Eichner, 2007; Bergeron, 2003). Besides, exercise-induced-sweating causes fluid to shift, from interstitium, to intravascular-space (Bergeron, 2008), which alters excitability on selected nerves (Miller *et al.,* 2010). However, according-to Armstrong & Cross (2013), the-pathophysiological basis for this-proposal is not clear and has not been formally-outlined.

Dehydration theory

According to the-dehydration-theory, excessive-sweating is the-primary-cause of EAMC (Braulick *et al.,* 2013; Bergeron, 2008; Jung *et al.,* 2005; Stone *et al,* 2003; Schwellnus *et al.,* 1997). This-theory is propagated, because-of the-association of heat-illness with cramps. However, Armstrong & Cross (2013) pointed-out, that the-dehydration-theory is based-on anecdotal-observations, with no actual-measures of hydration-status reported. In the-more-recent-studies by Drew (2006); and Sulzer *et al.* (2005), in-which calculated-body-weight-changes and volume of blood or plasma, were used as-indicators of hydration status, the-hypothesis of a-direct-relationship, between dehydration and muscle-cramping, was not supported.

Environmental theory

The-environmental-theory suggests that exercising in hot-conditions and the-subsequent-electrolyte-loss and dehydration, results in-EAMC (Bergeron, 2003; Schwellnus *et al.,* 1997; Armstrong & Maresh, 1993). However, Armstrong & Cross (2013), have argued that EAMC is not directly-related to an-increased core temperature. At-rest, however, passive-heating does *not* result in skeletal-muscle-cramping and cooling does not relieve it, so it-is unlikely that exercising in hot-conditions causes secondary physiological changes, which can cause EAMC.

Altered neuromuscular control theory

During sports-competition, training, and a-variety of other-intense-physical-activities, repeated or extendedloading, on selected-muscles can lead-to localized-muscle-fatigue. The-altered-neuro-muscular control-theory suggests that muscle-fatigue disrupts the-normal-functioning of peripheral-muscle-receptors, causing an-increase in excitatory afferent-activity, within-the-muscle-spindle, and a-decrease in-inhibitory afferent-activity, within the-Golgi-tendon-organ, both of which then lead-to an-increase in-alpha motor neuron-discharge to the-muscle-fibers, producing a localized-muscle-cramp (Miller, 2015; Schwellnus *et al.,* 1997; Ruff, 1996).

In-simple-terms, according to this-theory, EAMC is a-result of a-muscle-fatigue (Schwellnus, 2009; Bentley, 1996). Besides, according-to O'Connell *et al,* (2013); and Schwellnus (2009), primary-factors, in- the-development of EAMC, are: ''increased exercise intensity or duration, development of muscle fatigue, muscle contraction in a shortened position, and possible tissue damage''. **Figure 2** shows the-system of factors, associated with EAMC, according to this-theory.

The-Altered-neuromuscular-control-theory seems to-be the-most scientifically-acceptable-theory, suggesting that EAMC are caused by an-imbalance, between increased-afferent-activity (e.g., muscle spindle), and decreased-inhibitory afferent-activity (e.g., Golgi-tendon-organs), which leads-to increased motor neuron-activity and muscle-cramping, especially with muscle-contraction in a-shortened-position. This is also supported by a-laboratory-based exercise-protocol, specifically-designed to-cause premature- fatigue, of the-calf-muscles, has been shown to-result in a-high-incidence of muscle-cramping, during exercise (Jung *et al.,* 2005).

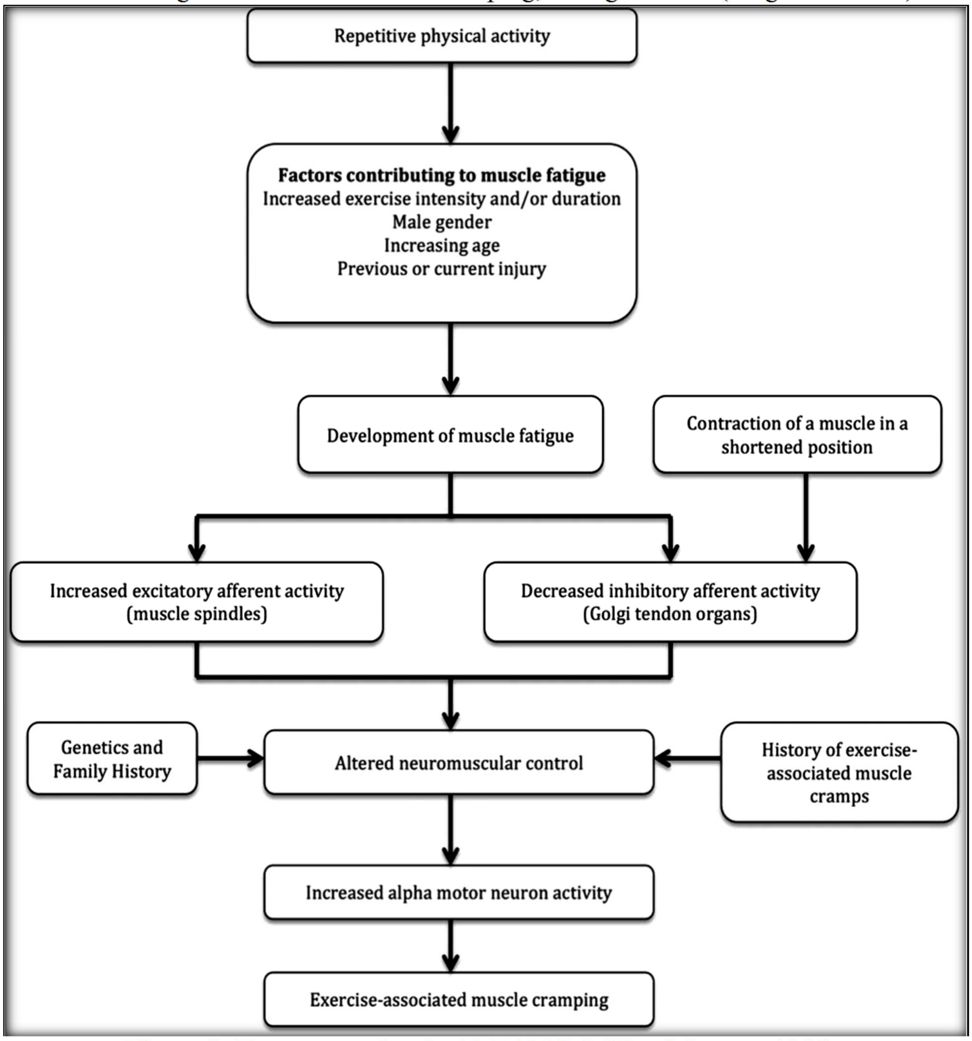

Figure 2: Factors associated with EAMC (Miller & Layzer, 2005).

Among other-theories, that have been-proposed for the-etiology of EAMC, are an-inadequate-intake of carbohydrate, glycogen-depletion, poor-biomechanics or running-gait, hilly-terrain, and lack of adequate massage, before and during-a-game (Schwellnus *et al.,* 2008). Cramp-discharges may-also be attributed to the-fact that terminal-branches of motor-axons are exposed-to increased-concentrations of excitatory extracellular-substances, such-as acetylcholine or electrolytes (i.e., sodium and potassium) (Ruff, 1996; Layzer, 1994; Sjogaard *et al.,* 1985).

The-electrolyte-imbalance-and-dehydration-theory suggests that EAMC is related to the-decreased concentration of serum-electrolytes, particularly sodium and chloride, resulting-from excessive-sweating or over-consumption of water (Schwellnus *et al.,* 1997; Armstrong & Maresh, 1993; Ladell & Camb, 1949). On-the-other-hand, according-to Armstrong & Cross (2013):"muscle fatigue is now acknowledged as the principal predisposing factor in the development of EAMC". This-study, however, supported Miller and his colleagues, who pointed-out, that (Miller *et al.,* 2010):

> Because EAMC occur in a variety of situations, environmental conditions, and populations, it is unlikely that a single factor (e.g., dehydration, electrolyte imbalance, or neuromuscular factors) is responsible for causing them directly. It is more likely that EAMC are due to a combination of factors that simultaneously occur under specific physiological circumstances in each athlete.

Muscle-cramping can-also-occur as-a-symptom for a-variety of medical-conditions, including: Hypo-thyroidism, vascular-disorders, metabolic-myopathy (caused by glucose-metabolism-defects), radiculo-neuropathy, serum-deficit of magnesium, Parkinson's disease, diabetes mellitus, peripheral-neuropathy, electrolyte-disorders, venous-insufficiency, or chronic-obstructive arterial-disease of the-lower-limb (Parisi *et al.,* 2003; Tarnopolsky, 2002). Muscle-cramps are also part of certain-conditions such-as: Compression of nerve; kidney disorder, hypo-glycemia; and anemia (Qiu & Kang, 2017).

Cramps also may-occur as a-side-effect of certain-toxic and pharmacological-agents/drugs (e.g., lipid-lowering-agents/ diuretics, blockers, anti-hyper-tensives, agonists, insulin, oral-contraceptives, and alcohol) (Qiu & Kang, 2017; Maquirriain, 2007).

Moreover, according-to Armstrong & Cross (2013); Schwellnus (2007); and Manjra *et al.* (1996), potential-contributing-factors in these-theories include: genetic-predisposition and family-history; lack of adequate-massage, before and during a-game; insufficient-carbohydrate loading or carbohydrate inadequacy, during-exercise; ground-conditions (ground 'hardness'); and poor-biomechanics or poor-running-gait.

1.5. EAMC: Treatment-approaches, including preventive-measures and therapeutic-massage.

Schwellnus (2009) pointed-out, that severe-EAMC, during-sporting-events, requires urgent-medical attention. Effective-immediate-treatment is to-increase inhibitory-input to the-muscle, either by stretching, or by electrical-stimulation of the-tendon. Immediate-treatment of the-acutely-cramping-athlete requires passive-stretching of the-affected-muscle-groups, and maintaining the-stretched-position, until fasciculation ceases. Other-measures include cooling the-skin-temperature, when excess-heat is an-issue, as-well-as oral- hydration. Drug-therapy (e.g., diazepam, magnesium, quinine, calcium) however, is not recommended.

When the-urine is dark or scarce, during the-first-hours, fluid-replacement, along-with further-clinical and laboratory-study is recommended (Maquirriain, 2007; Sulzer *et al.,* 2005). Besides, Miller (2014) also recommended: thermotherapy, cryotherapy, sports-drinks, salt and electrolytes, pickle-juice, intravenous infusion, and trans-cutaneous-electric nerve-stimulation. Recently, an-effort has-been-devoted to-evaluate a-method of using food-extracts like peppers, ginger, mustard, and cinnamon to-resolve EAMC.

Preventive-measures include reducing-training and competition-intensity and duration (e.g., by lowering overall-exercise-intensity and altering the-load on the-distressed-muscle(s)), as-well-as improving conditioning, and range of motion, through appropriate and regular-individualized-progressive fitness and stretching-programs. Adjustments to equipment-configuration and selection (e.g., bicycle-seat and handle position, shoes), biomechanics, and relaxation-techniques may also-help to-avert, or delay, fatigue-induced muscle-cramping (Roeleveld *et al.,* 2000; Bentley, 1996; Riley & Antony, 1995). In addition, Bergeron (2008) pointed-out, in his-study, that fluid-replacement (89.8%), proper-nutrition (72.8%), electrolyte replacement (70.3%), and proper-stretching (55.8%) were perceived as extremely-successful prevention strategies.

On-the-other-hand, the-athlete, presenting-with severe or generalized-cramps in-muscles, not subjected to exercise, or with localized-cramping together-with-confusion, altered-state of consciousness, or other-signs of central-nervous-system-involvement, should receive emergency-medical-attention. These patients are likely-suffer-from a-systemic-disease, such-as a-metabolic-disorder (Maquirriain, 2007; Tarnopolsky, 2002). Such-patients require immediate-hospitalization, to-rule-out volume-depletion, electrolyte-imbalance, acute-renal-failure, intracranial-disorders, or other-systemic-conditions (Maquirriain, 2007; Coppin *et al.,* 2005).

Massage-therapy as therapeutic-treatment of EAMC is the-primary-focus of this-study. Massage therapy is designed to-stretch, calm, revitalize, and loosen the-affected-muscles, improve blood flow, facilitate the-removal of metabolic-wastes, resulting-from exercise, or inactivity, and increase the-flow of oxygen and nutrients to the-cells. In-addition, massage stimulates the-release of endorphins (the-body's natural-painkiller) into the-brain and nervous-system (Zainuddin *et al.,* 2005; Robertson, 2004; Hilbert *et al.,* 2003; Hemmings *et al.,* 2000).

Massage, and associated-soft-tissue-treatment, is an-important-component of the-training-process for many-elite-athletes, as muscle-tightness interferes with the-nerve-feedback-mechanisms, which ensure efficient and smooth-control of movement, so necessary in-competitive-sport. Indeed, according-to Bergeron (2008) and Jönhagen *et al.* (2004), the-request for sports-massage, among competitive-athletes, has seemed to-increase during the-past-years. Many-top-level-athletes consider this-treatment as-enhancing their-recovery, after training and competitions, as-protection from overuse-injuries, and as reducing the-risk of delayed-onset-muscle-soreness (DOMS) (see Thomson *et al.,* 2015). DOMS normally follows unaccustomed-eccentric-exercise, and the-peak of muscle-soreness is seen 24 to 72 hours (Stone *et al.,* 2003; Friden & Lieber, 2001; Byrne *et al.,* 2001; Angus, 2001; Armstrong *et al.,* 1991), after-exercise.

In-addition, it has-been-proposed that the-mechanical-pressure, during-massage, alters neural excitability, and these-neural-changes may-reduce the-potential for cramping (Nelson & Churilla, 2016; Behm *et al.,* 2013; Lee, 2009). Sefton et al. (2012) discovered a-reduction in the-Hoffman (H)-reflex, which was-used to-measure the-excitability of the-motor-neuron-pool, in-study-participants, who received a 1-hour full-body-massage. Analogous, Behm *et al.* (2013) found that massage decreased spinal-reflex excitability, with significant-reductions, in-subjects, who received 30 seconds of a percussive-massage stroke. They, however, pointed-out, that further-investigation is warranted to-determine whether treatment variables, such-as the-relative-timing of massage, depths of pressure, speed of stroke, and type of massage stroke, influence EAMC, without negatively-impacting-performance.

Numerous-studies have-been-conducted, regarding the-capabilities of effleurage-application, on the- calf-part, and it was-found that there are essentially-perceived-effect of massage on the-circulation, where superficial-effleurage should be centripetal (Halperin *et al.,* 2014; Miller *et al.,* 2010; Bergeron, 2008; Callaghan, 1993). Moreover, in-accordance-with the-muscle-spindle/GTO-imbalance-Theory, stretching, and frictional-icing-massage, of the-affected-muscle-groups, may-help to-relieve painful-muscle-spasm, in acute-cases (Maquirriain, 2007), and hence has been frequently-recommended in-the-literature (Miller & Layzer, 2005; Kenefick *et al.,* 2001; Schwellnus *et al.,* 1997; Bentley, 1996; Bergeron, 1996; Guissard *et al.,* 1988).

1.6. Research-purpose.

EAMC can be severe, reguiring immidiate-medical-attention. According-to Venable (2009), the-most effective-way of muscle-spasm-relieve, is by the-use of drugs, which reduce the-firing-effect of the motor neurons, or act to the-central-nervous-system, to-reduce pain-sensitivity. One of these-drugs is Quinine-Sulfate; however this-drug causes the-feeling of nausea, dizziness, partial-blindness, and even death; these-side-effects being greater-than the-advantages, therefore, this-drug is rarely-used (Timothy, 2005). In other-severe-situations, the-patient is advised to-undergo a-surgery, known as-orthopedic-surgery, to-correct the-muscle-situation.

On-the-other-hand, massaging-devises are relatively-effective and harmless, in-mitigating EAMC. Preliminary-assessment showed, that the-majority of massaging-devices rely on external-power (such-as batteries, electricity), this power-requirement, however, could be a-big-disadvantage, when such-sources do fail. For-example, athletes may experience EAMC, at the-middle of the-field, where there is *no* electric- source, which endangers their-mobility and even their-career.

In-addition, the-author was not able to-trace freely-available-published-literature on the-design of massaging-devices; with-exception of one-article, by Kamat *et al.* (2017), who described a-design a-manual calf-massager for prolonged-standing-workers. Hence, there is a-gap, to-be-filled.

Considering the-above-limitations, the-aim of the-current-research was to-design a-manual, simple, cost-effective massaging-device, that can-be-used to-manage EAMC, in the-field.

2. Materials and Methods.

2.1. Concepts of Engineering-design and Conceptual-design.

Design can-be-described as a-set of decisions, taken to-solve a-particular-set of product-requirements. Design is part of a-human problem-solving-activity, beginning with a-perception of a-gap in a-user- experience, leading-to a-plan for a-new-artifact, and resulting in the-production of that artifact. Product design is conceiving and giving form to goods and services that address needs (Burdekin, 2007). Within the product-development-process there are several-phases: idea-generation, product-definition (also-called product-planning), conceptual-design, detail-design, and embodiment-design (Timings, 2000).

The-conceptual-design-phase is the-most-important-phase in concurrent-engineering, after the-project planning-phase or product-definition. Approximately 80% a-product's life-cycle costs are committed through design-choices, such-as materials and manufacturing-process-selections in this-phase. Conceptual- design comprises concept-definition, exploration, evaluation, and selection (Allen & Carlson-Skalak, 1998). The-inputs, into-the-design-process, are shown in-**Figure 3**.

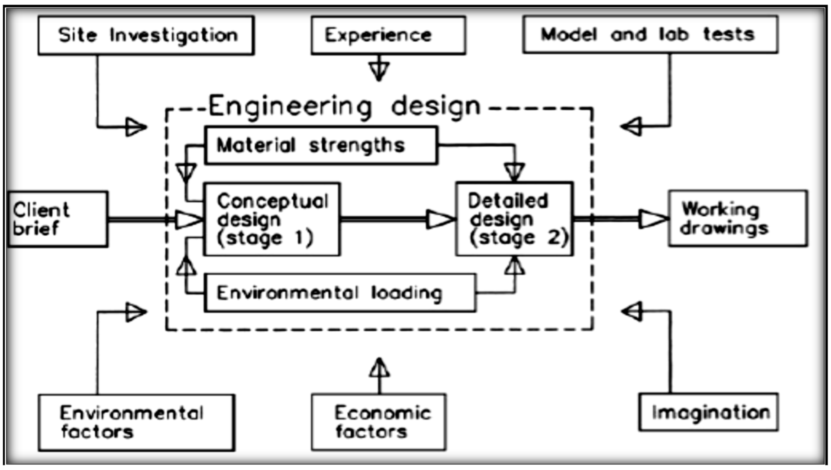

Figure 3: Inputs into the-design-process (Arya, 2009).

2.2. Steps and tools involved in the-current-study.

This-study was focused on product-design, where several-tools have to-be-applied. Design-tools enable product-designers, to-structure and formalize parts of their-design-steps (Jangager, 2005). In-particular, this study is based-on the-bottom-up-approach, where the-design starts-with specifying-requirements and capabilities of individual-components (see Crespi *et al.,* 2011).

In-particular, to-achieve the-study objectives, the-following-steps were conducted: (1) formulate design-problem with target-specifications; (2) prepare and analyze design-alternatives; (3) conduct design simulation and analysis; and (4) establish optimum-conceptual-design, based on the-analysis of results.

Romer *et al.* (2001) stated, that traditional-tools, such-as sketches and simple-physical-models are very-useful and cost-efficient, in-generating design-solutions, in early-phase of design-process. Besides, most of the-times (this-study included) design-problems, are open-ended; they do not have a-unique, or the only-one correct-solution, though some-solutions will, clearly, be-better, than others. In-this-regard, three design-alternatives, is to-be hand-sketched.

Product-designers utilize a-wide-variety of design-tools, ranging from sophisticated-computerized information support-systems, such-as CAD-systems, to inexpensive-memory-aids, such-as pencil and paper (Love, 2003). This-study, for-example, used a-pencil and paper, as tools, for free-hand-sketching, of three alternative-designs; and a-database, as a-tool for information-storage and retrieval. The-design also applied fundamental-Engineering-principles of product-design. Besides, this-study was-carried-out in-compliance with ISO7250: 1996 (Basic-human-body-measurements for technological-design).

Engineering-design can-be-considered as a-complex-process, made of a-series of decisions (i.e., 'either–or') and compromises (a trade-off) (Allen & Mistree 1997; Rajan 1996). The-existing related literature proved that decision-making-methods could-be very-useful in-engineering-design (Chen *et al.,* 2013; Krishnamurty, 2006). According-to Renzi et al. (2017), who reviewed the state-of-the-art knowledge on decision-making methods: "A-decision generally-implies the-selection of a-proposal, aiming at recognizing the-one, that best-fits with goals, objectives, desires, and values". Renzi *et al.* (2017) further indicated, that according-to the-nature of the-decisional-problem, proposed (multiple-criteria decisional problems, unstructured/ill-posed-problems, and structured-problems), decision-making-methods for solving engineering-design-problems involve three-main-groups: (i) Multi-Criteria Decision-Making (MCDM) methods (Belton & Stewart, 2002) (ii) Problem-Structuring-Methods (PSMs) (Rosenhead & Mingers, 2001); and (iii) Decision-making Problem-Solving (DPS) methods (Ernawati, 2015). This-study used a-standard Engineering-Design Weighted-Decision-Matrix (EDWDM), to-select the-best design-alternative.

2D-drawing, of the-best-design-alternative, was created via computer-aided-design (CAD) AutoCAD-software. Furthermore, identification of specific-anthropometric-dimensions and the-design target-population was identified and specified. These-dimensions were used for the-preliminary-design.

Simulation of Stress-Analysis/Single-Point Static-Analysis (to detect and eliminate rigid-body-modes; and separate stresses across contact-Surfaces) was done by Autodesk-Inventor-Version: 2016 (Build 200138000, 138).

According-to Ashby (2004), first-consideration, in materials selection, is on the-functionality of the material, the-main-goal here is being-able to-produce products that function effectively, safely, at acceptable-cost. This-study adopted the-interaction of function, materials, shape, and manufacturing- processes from Asbhy (1999), and the-interaction of use, function, materials, and shape, from Roozenburg & Eekels (1995).

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3. Results and Discussion.

3.1. Document Analysis.

A-number of relevant-International-patents (developed by individuals, as-well-as design-companies) were reviewed; examples included: US 7223251 B1 (2007); US 6027434 (2005); US 6784127 B1 (2004); US 6645089 B2 (2003); US6638184 B2 (2003); US 6499485 B1(2002); US 6241696 B1(2001); US 6210304 B1 (2001); US 6146343A (2000); US 6093159 A (2000); US5868689 A (1999); and D403076 S (1998).

Figure 4 shows selected-examples of most-recent-patents, reviewed.

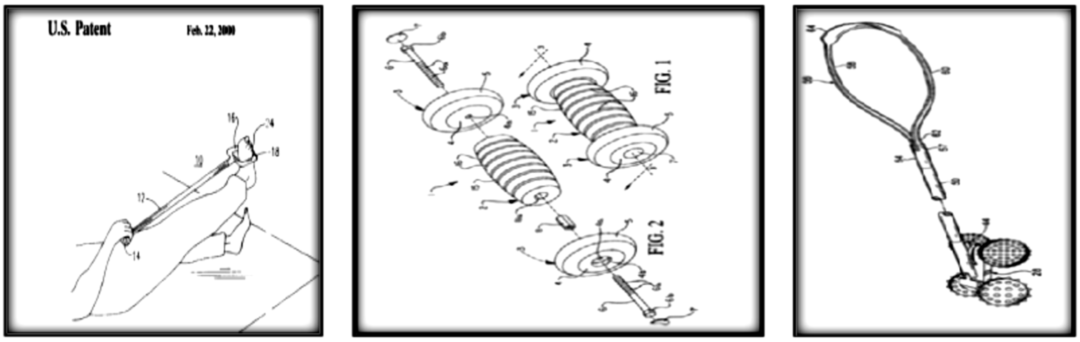

Figure 4: Selected Patents, reviewed.

Key: left - US 6027434 (2010); middle - US 7223251 B1 (2007); and right - US 6027434 (2005).

The-following-limitations were identified in the-specified-patents:

(i) In-the-Patent US 6027434 (2010), the-major-limitation is the-rigidity of the-design, as the-device cannot be used universally (e.g., for athletes of different-hight). Second-limitation is that the-device only utilizes stretching-function; no massaging. Third, the-device tends to-pinch the-sides of the-users-feet, as tension is applied to-pull the-leg. Besides, this-device may only be limited to-handle the-cramps of the quadriceps, and can hardly-be-used for the hamstrings, since the-stretching-direction cannot be changed.

(ii) In-the-Patent US 7223251 B1 (2007), most-people, using rollers to-relieve muscle-spasms agree that they are quite-effective, but it requires technique, especially if the-roller lies on the-ground, as suggested in this-design.

(iii) In-the-Patent US 6027434 (2005), the-spherical-shape of the-roller does not bring-about adequate-massaging-action and it's generally more-difficult to-bring such-balls to-rotate. The-manner, in-which these-rollers are attached at the-end of the-handle, is not clear whether massaging of the-leg occurs when the-roller-arrangement is intact, or that they have to-be-detached. Usually, one needs a-closer contact with the-massaging-rollers of which this-massaging-system entirely-depends-on the-amount of pressure the-user applies.

The-study also examined selected-examples of available, on the-market, devices. **Figure 5** shows some-examples of the available-devices.

Most-of the-available-devices, reviewed, utilize the-principle of electrotherapy, which are powered electrically, used transducers to-produce a-vibration-motion. Some of the-electrotherapy-devices are the FES (Functional-Electrical-Simulation), which mainly-stimulates the-muscles of the-ankle and the-foot, when one is walking (Bailey, 2011). The-FES-pad is attached on the-particular-foot-muscle and triggers it, during-walking. TENS (Trans-cutaneous Electrical-Nerve-stimulation) is a-pad, attached to-the-muscle, and generally affects the-pathway of pain to-the-brain, hence eases the-pain. TENS-devices, however, could cause some-skin-irritation with use (Bailey, 2011). So-many-devices have-been invented and currently being-sold, however, these-devices are quite-expensive, for any-developing-country, Kenya is *not* an-exception.

Figure 5: Selected-examples of the available-devices, to relieve EAMC.

Keys (from extreme-left (i) … to extreme-right (iv)**):**

(i) - Calf Braces; (ii) - Power massage device;

(iii) - Lumiwave Theraphy Device; and (iv) - Laser pain relief device.

(i) In-Calf-Braces-device, calf-compression-brace is designed to-support the-calf and shin in-case of a muscle-strain or a-muscle-pull, they are used to-provide-compression to the-affected-calf-area (Mathews, 2016);

(ii) Power-massage-device (by Brick, 2017), has a 12V battery and makes 2000 strokes per-minute and costs $399 which is quite-high. Another-limitation is that the-speed of the-device is constant, giving no room for adjusting (Brick, 2017), and again the-noise, it produces, is quite-high, especially when it has to-be-used to-massage areas near the-ear (Matt, 2018);

(iii) Lumitherapy-Device infrared-Light-device uses infrared-light to-reduce muscle-pain, joint-pain and stiffness, with the-light, emitted ensuring proper-blood-circulation and also relieves muscle-cramps. The-device can have 4 pods or 8 pods, going at $512 and $712 respectively, at the-Amazon. One-user, in their-chart-review-site commented that the-device was not powering properly, other-users claim that this- device produces an-annoying buzzing-sound; and

(iv) Laser-pain-relief-device consists of a-flex-pad, on-which a 60 LED (Light Emitting Diodes) infrared and red-light, arranged in an-array. The-infrared-light supposes to-stimulate blood-circulation, enables muscle-relaxation, and relieve muscle-spasms, pains, aches, sprains, strains, carpal-tunnel Syndrome, and other-physical-ailments. Going at $180.99, this-device can be used for therapeutic purposes, and claimed to-cause faster-healing of tissues. A-disappointed-user, however, explains how the-product stopped working, just after six-months of using it, and the-pad and the-LED separated for other-cases (Grainge, 2016). Another-complains is that the-LEDS are too-bright, and one would-require to-buy safety glasses, while using them.

3.2. Identification of target-specifications/objectives of the-massaging-device.

Document-analysis revealed that the-selected-reviewed-devices have a-number of limitations. For-example, some of them: (1) are lacking massaging and stretching capability; (2) cannot be used universally; (3) are bulky and heavy; (5) are expensive to-buy and to-maintain; (6) are *not* effective in-severe-cases of EAMC; (7) produce extreme-vibrations and make a-buzzing-sound; (8) use power (e.g., electricity; inverter; battery) and use potentially-harmful infrared-light, for operation; and (9) can have side-effects, e.g., skin irritations, and general-discomfort, among-others.

The-current-design will focus on addressing the-above-limitations; and therefore, the-device should be: (i) capable of effectively-relieving EAMC, *via* simultaneous-compressive and massaging-functions; (ii) adjustable, to-carter for several-sizes (e.g., height); (iii) compact, lightweight, foldable, and portable; (iv) reliable (*no* need for power; manually-driven); (v) cost-efficient (affordable); (vi); durable and made of compatible-materials (non-toxic); (vii) manually-operated and, hence, relatively-quiet; (viii) serviceable (consisting of few-easily-replaceable-parts); (ix) thermally-comfortable and bio-compatible; and (x) environmentally-friendly (can be easily and economically-recycled).

In-particular, the 3 major-utility-characteristics of the-device are: functional-efficiency, adjustability, and thermal-comfort-ability. It also should-be portable, easy to-store, and to-transport. Bio-compatibility was also-taken into-consideration as a-constraint; the-device must *not* irritate the-skin, or result in a-higher surface-temperature. With proper-material-choice, that incorporates sweat-wicking or a reasonably-high thermal-conductivity, the-body-heat can-be-dissipated, easily, to-prevent profuse-sweating and, hence, discomfort.

Besides, a-device usually comprises of various-parts. The-utilitarian or functional-part is the-one that truly-performs basic-task, which prompts the-execution of the-segment. The-non-functional-part does *not* have real-work in-segment-presence, but rather it needs to-do-with support, spreads, examination, and aesthetical-worth, and therefore, the-number of non-functional-parts should-be-reduced to-cut the-cost (Juvinall & Marshek, 2012; Budynas-Nisbet, 2008).

In-summary, the-device should-be: Efficient (relives calf-muscle-cramps); Functional (easily maintained, user-friendly); Pleasant in Appearance (suitable size and shape, attractive-design, good finishing); Durable (*not* easily-broken, stable, and robust-design, strong sound-structure); and Safe (harmless to the-user, no-side-effects, environmentally-friendly).

To-achieve these-criteria, structurally, all-the-components should: (a) be symmetrical (and have polar-geometry-mark), if possible, as this also-helps in-manufacturing; (b) have consistency, in the-dimensions, used for feeding, orientation, and location; (c) have location-points; and (d) be functional, hence, components which are *not* important/functional should-be-eliminated.

3.3. Free-hand-sketches of design-alternatives.

The-study limited to three-design-alternatives, developed, by the-design-team, which are shown in-**Figure 6**. Some-preliminary-calculations were done, at the-same-time, which might-be-required to-substantiate ideas and to-establish approximate-sizes.

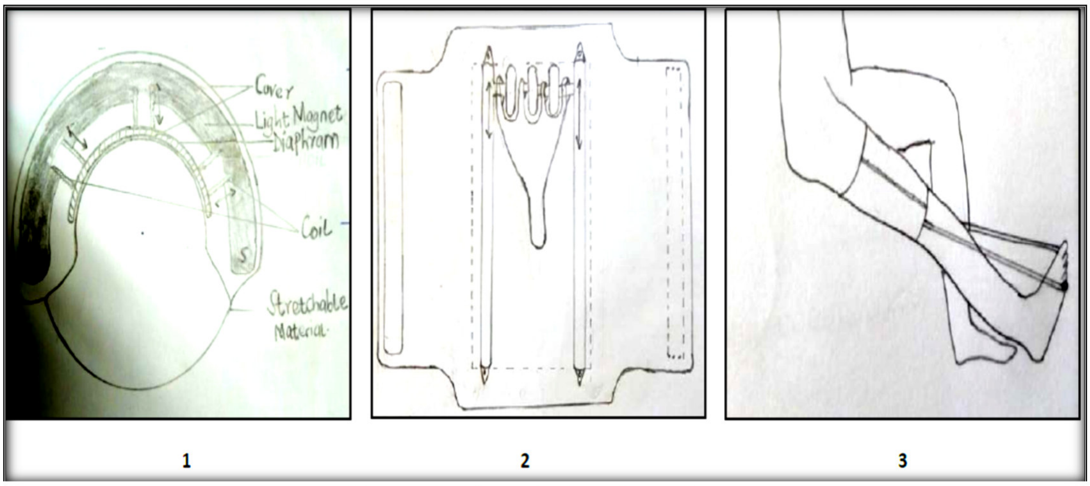

Figure 6: Three design-alternatives.

The-design-alternative (#1 in Figure 6) is an-electro-mechanical system, it-is to-be-composed of a-coil, a-light-magnet, and a-diaphragm, as the-basic-components, with a-stretchable-covering-material. The device can fit both; on the-calf and on the-thigh-muscles. The-electrical-system involves the-supply of Alternating-Current (AC) to the-coil, which is within the-magnetic-field, of the-light-magnet. As the magnet's magnetic-field and the-induced-magnetic-field on the-coil interacts, the-coil moves-inwards, pushing the-diaphragm. This-enables the-device to-give a-pressing-action, on the-affected-muscle, supposedly relieving the-pain.

The-second-design is made-up of a-wrap-round-piece, on-which massage-wheels are mounted, so-as to-enhance the-massaging-action. Mounting gives the-rollers better-massaging, since the-pressure is applied on the-muscle the-wrap-round-piece. The-massaging-wheels transverse the-muscle by the-use of a-handle that is attached to the-axle of the-wheels, and the-motion is guided by a-rail. The-interior of the-device is made of a-layer of protrusions, which give a-finger-like-massage, by smoothly-penetrating to the affected-muscle, this with the-wheel massaging-rollers give a-double-action-massage.

The-third-proposed-device will be using primarily a-stretching-function, while massaging is secondary. The-inner-part of the-device will-be-spiked, hence, on stretching it will produce some-close-skin-contact. The-device is to-be adjustable, to-accommodate several-sizes.

3.4. Selection of the best-design-alternative.

Alternative design # 2 was selected, via a-EDWM, with the-highest-score of 0.72; while Alternative # 1 scored 0.63; and Alternative # 3-- 0.47. Analogous to Starovoytova & Namango (2016), to-confirm the- choice, additional-method, of selection of best-design-alternative, was used, namely 'D & R-method'.

3.5. Preliminary selection of material-groups.

In-preliminary-selection of material-groups, Engineering-materials are sorted into the-family-groups, such- as: polymers, metals, ceramics, glasses, natural-materials, composites, and hybrids; each of these families/ groups has a-set of attributes (property-profile), which can be plotted in a-material-property-chart (e.g., Ashby-Materials Selection-Charts (see Ashby, 2005).

Besides, according-to Jerz (2014), the-selection of materials goes-through four-steps: translation, screening, ranking, and support-information. Translation-stage involves establishing the-constrains on material-properties and the-process-attributes. The-properties for consideration, in-this-study, were-limited to: (i) technical-properties of materials (e.g., density, conductivity, strength, etc.); (ii) manufacturing of materials (e.g., easy to manufacture with existing-manufacturing-facilities); (iii) economic-properties of materials (availability and cost for material and production); and (iv) ecological-properties of materials (recycle-ability, sustainability, etc.). Besides, materials, which come in-contact-with the-human-skin, should-be carefully-selected; this is due-to some-skin-diseases, such-as Eczema (recurrent-skin inflammation) (Mason, 2009), therefore, the-materials-bio-comparability will be also under-consideration.

Natural-chrome-tanned-leather has excellent-mechanical-properties of bursting, and thermal-resistant properties (Yu, 2013); however it-is expensive, and the-chrome-tanned-leather may *not* be compatible-with some people's skin, especially those suffering-from the-eczema-disease of the-skin (Mason, 2009). Synthetic-leather is, hence, to-be used, due to its-flexibility, comparability, availability, and price. The handle is to-be-made of wood, due to its-specific-gravity, of which the-general-substance that make it up is 1.5 regardless of the wood-type (Green, 1999). Galvanized-steel-sheets, which do *not* easily-rust, will be used for rails.

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3.6. Design-target and Anthropometric-measurements, to be used in the-design.

50th percentile (covering 90% of the-population) adult-male, was selected, as most-appropriate design target-population. **Figure 7** shows the-relevant-anthropometric-dimensions, needed for the-design. International-Standards, for Anthropometric-Assessment by Marfell-Jones (2001) and Anthropometrical- data from Fryar (2012), were used, to-obtain one-dimensional-values for these-dimensions.

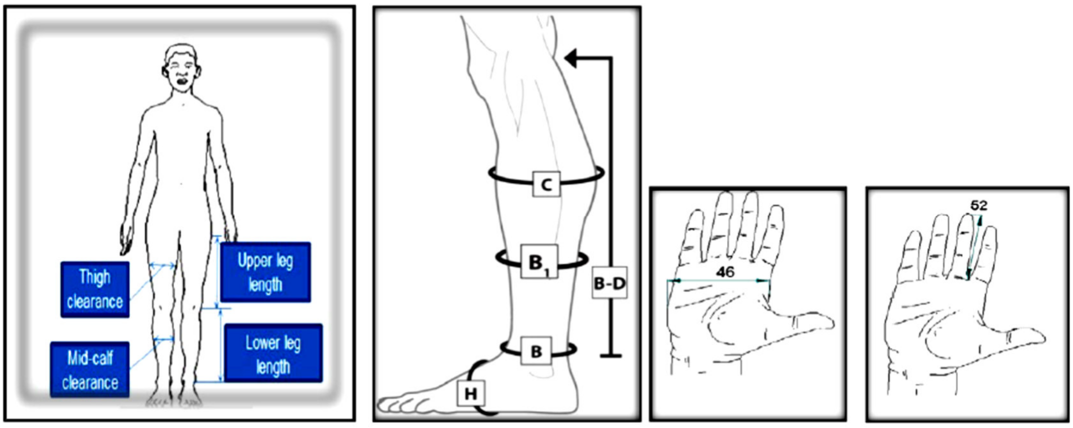

Figure 7: Relevant Anthropometric-dimensions.

Note: Dimensions B and H were *not* considered in this-design.

3.7. Description of the best-design-alternative.

Fundamentally, fatigue is occurring due-to the-Isometric-Contraction, with the-increasing lactic-acid accumulation. Influence of massage on Muscle-Blood-Volume (MBV) is particularly-important, in this design-alternative, since according-to Imai *et al.* (2016); and Mori *et al.* (2004), the-effect is thought to help enhance-removal of metabolic-waste by-products, such-as lactic-acid, thus enhancing recovery from muscle-fatigue. The-rotating-roller will give superficial-massage and provide soft-tissue manipulation, towards the-calf-parts, achieving relaxations on-muscle-activity, and consequently improving blood- circulation in the-body.

Figure 8 shows the-ideation-diagram, which is the-general-plan-view of the-proposed-device. The yellow outer-lines represent the-synthetic-leather-part, to-wrap-around the-calf-muscles. It spans for 430mm, with the-flaps, where the-Velcro-strips are attached, so as to-allow adjustment. The-blue-parts are the-rails, on which the-massaging wheel-axel is to-move-through. The-part, represented in-green, is the massaging-system, made-up of the-massaging-wheels, the-axel, and the-handle. Lastly, the-part, represented in-pink is the-spiked-area, which surface, gives a-finger-like-massage to the-muscles.

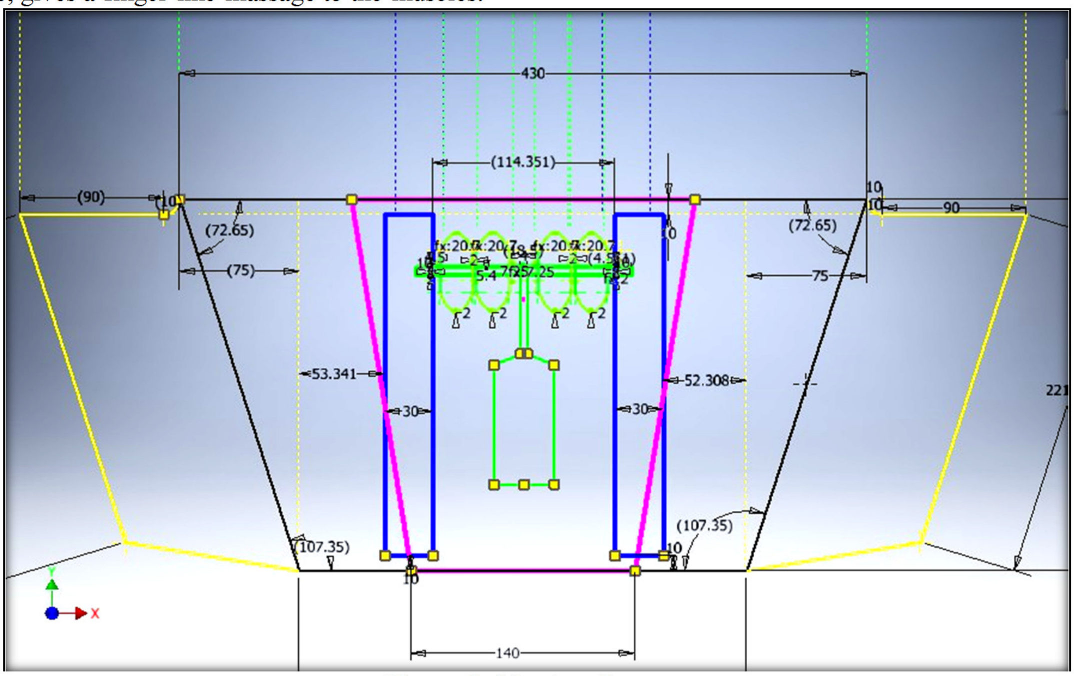

Figure 8: Ideation diagram.

The-height of the-rail should be such, to-allow free-rotation of the-rollers, massage, as-well-as support on

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the-leather-surface by rivets. Positioning of four-Velcro-strips, for adjustability were calculated to be positioned in the-upper-side at 17, 21, 25, and 29cm, from the-centre and on both-sides, and at points 10, 13, 16, and 19cm (on the-lower-side). The-handle-dimensions was calculated, based on the-design-target and arm-dimensions, at 25.45mm, and optimized (for ease of fabrication) to be 30mm. The-smallest-wheel, available, at the-time of the-study, was used.

The-layout was analyzed for forces, stresses, etc., and calculations, necessary were made to-be-certain that the-parts can perform satisfactorily. Engineering Design Software -- SolidWorks, 2013 (design and simulation tool) was used.

3.8. Simulation and Analysis.

By identifying the-loads, the-governing-failure-modes and tentatively selecting the-appropriate candidate material, the-failure-prediction-scenarios provide a-basis for choosing the optimal-combination of design parameters: geometry, material, and loads (Budynas-Nisbet, 2008). A-key-strategy in the-PDP (Product Development-Process) is to-avert failure of a machine/device/structure, by predicting and analyzing potential-failure-scenarios at the-design-stage, before it-is built. Factor of safety (FoS), also-known-as (and used-interchangeably-with) safety-factor (SF), and design-factor of safety (N), is a-term, describing the capacity of a-system, beyond the-expected-loads or actual-loads. According to Starovoytova & Njoroge (2016): "Essentially, the-factor of safety is how-much-stronger the-system is than it usually needs to-be for an-intended-load'. Factor-Safety of 4 was chosen, to-carter for changes in-material-properties, due-to normal-use and possible-extreme-weather. The-force of 557 Newton (since it-is the-highest-value for 95th percentile-male), was chosen for the-test (in-accordance with Schutte, 2007), where device ultimate tensile- strength at steady-loading is considered.

Operating-conditions for the-test are shown in **Table 1**, while **Table 2** specifies Reaction-Force and Moment, for Fixed-Constraint 1; and **Table 3** details the-summary of results.

Table 1: Operating-conditions.

Load Type	Force
Magnitude	557.000 N
Vector X	-17.667 N
Vector Y	211.753 N
Vector Z	514.876 N

Table 2: Reaction-Force and Moment, for Fixed-Constraint 1.

Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X,Y,Z)	Magnitude	Component (X,Y,Z)
Fixed Constraint:1	557 N	17.6667 N	45.7263 N m	45.3359 N m
		-211.753 N		4.73968 N m
		-514.876 N		-3.61744 N m

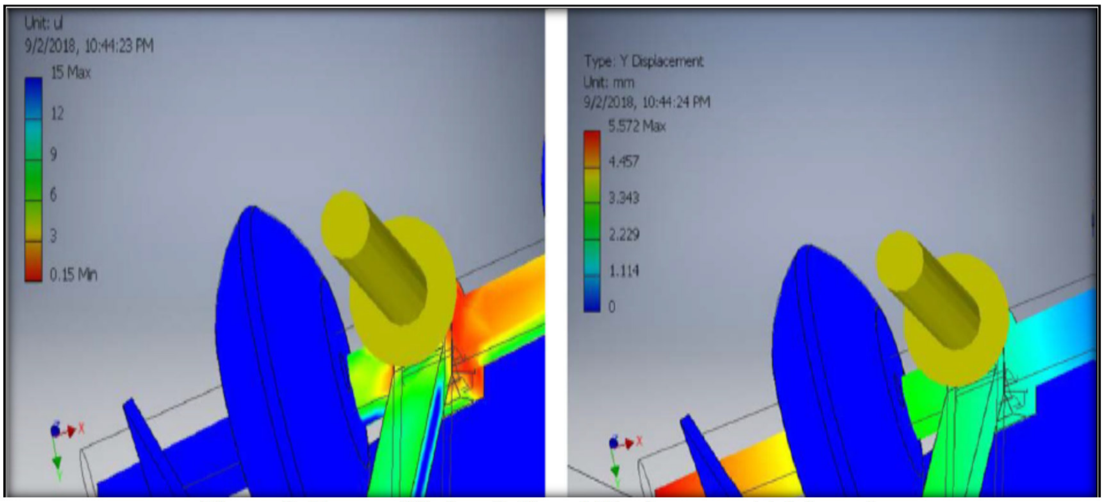

Figure 9: Factor of Safety (left) and Displacement (right) results.

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Table 3: Result Summary.

Name	Minimum	Maximum
Volume	453711 mm^3	
Mass	2.24525 kg	
Von Mises Stress	0 MPa	1372.3 MPa
1st Principal Stress	-207.62 MPa	1702.85 MPa
3rd Principal Stress	-1290.74 MPa	281.968 MPa
Displacement	0 mm	26.5655 mm
Safety Factor	0.150842 ul	15 ul
Stress XX	-635.321 MPa	667.882 MPa
Stress XY	-432.627 MPa	373.347 MPa
Stress XZ	-618.778 MPa	537.83 MPa
Stress YY	-453.349 MPa	470.41 MPa
Stress YZ	-373.512 MPa	414.638 MPa
Stress ZZ	-965.003 MPa	1518.52 MPa
X Displacement	-25.8904 mm	0.613642 mm
Y Displacement	-0.268855 mm	5.57165 mm
Z Displacement	-1.08114 mm	11.7049 mm
Equivalent Strain	0 ul	0.0057876 ul
1st Principal Strain	-0.000000203956 ul	0.00686072 ul
3rd Principal Strain	-0.00561485 ul	0 ul
Strain XX	-0.00215372 ul	0.00233776 ul
Strain XY	-0.00250727 ul	0.00216372 ul
Strain XZ	-0.0035861 ul	0.00311697 ul
Strain YY	-0.00242138 ul	0.00171521 ul
Strain YZ	-0.00216467 ul	0.00240301 ul
Strain ZZ	-0.00407341 ul	0.00579241 ul
Contact Pressure	0 MPa	2070.52 MPa
Contact Pressure X	-1926.3 MPa	904.793 MPa
Contact Pressure Y	-208.352 MPa	392.925 MPa
Contact Pressure Z	-1550.56 MPa	802.365 MPa

Figure 9 shows a non-uniform-displacement, along the-axel; besides the-Factor of Safety as-low-as 0.15Mn was reported, which is an-indication that the-axel could eventually fracture. Both-indicators necessitated corrective-measures, taken on the-handle.

Other-results, obtained from the-stress-analysis, include the-von-Misses-stress, the 1st and 3rd Principle-stress and strain, Equivalent-Strain and Contact-pressure.

3.9. Conceptual Design.

Conceptual-design of the-massaging-device was optimized, according-to results of simulations, calculations, and fundamental engineering-product-design-principles. **Figure 10** shows the-functional-elements/parts of the-massaging-device, while **Figure 11** shows its-assembly.

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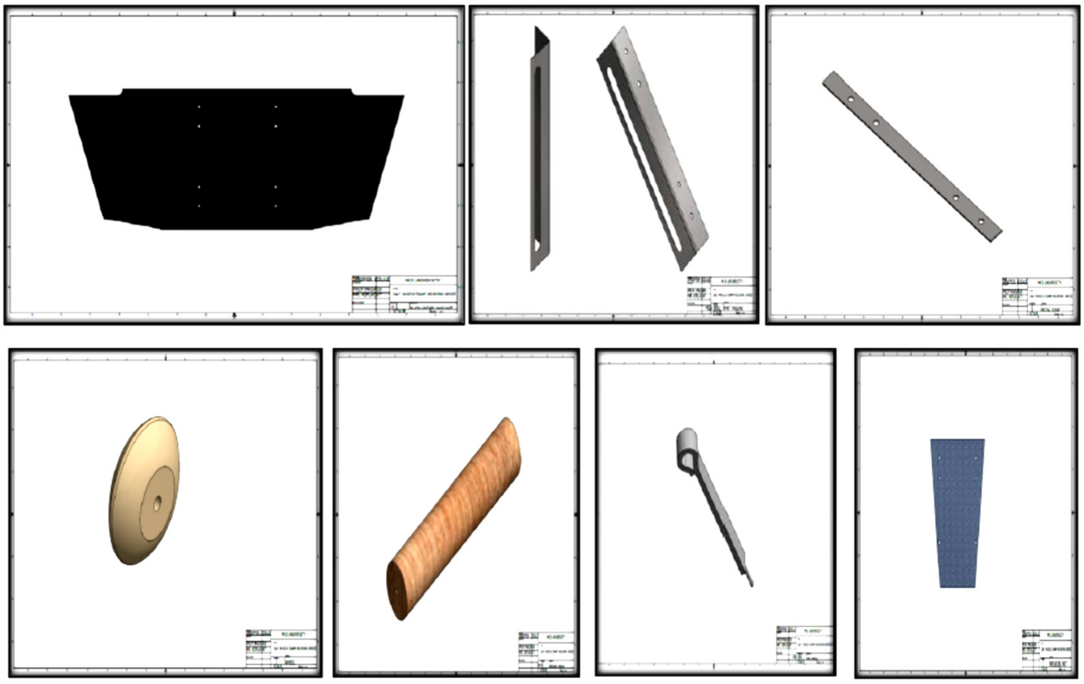

Figure 10: Functional-parts of the-massaging-device.

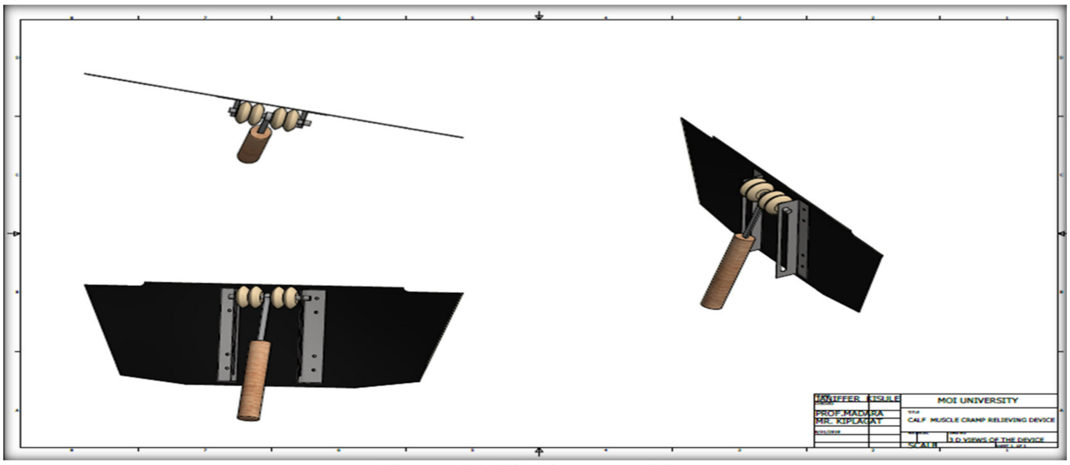

Figure 11: Device-assembly.

4. Discussion.

As stated-earlier, the-scope of the-project was-limited-to the-conceptual-design. On the-other-hand, prototyping and testing-stages, if carried-out, can give a-real-picture of the device-functionality. The-author proposes further-work on prototyping and testing to-be-carried-out, leading-to detail-design and embodiment-design.

Besides, the-general-contouring, of the-calf-area, of the-leg, is different, length and the-circumference varies-greatly, hence fitting the-wrap-round-piece. For-instance, **Figure 12** shows 9 combinations with different-length of leg (short, medium, and long), and varying-calves (small, medium, and big). The-study, hence, recommends further-studies, to-optimize the-dimensions of the-device, to-accommodate different shapes of calf-muscles; and the-use of stretchable-material (and also durable), which can easily take the- shape of the-leg.

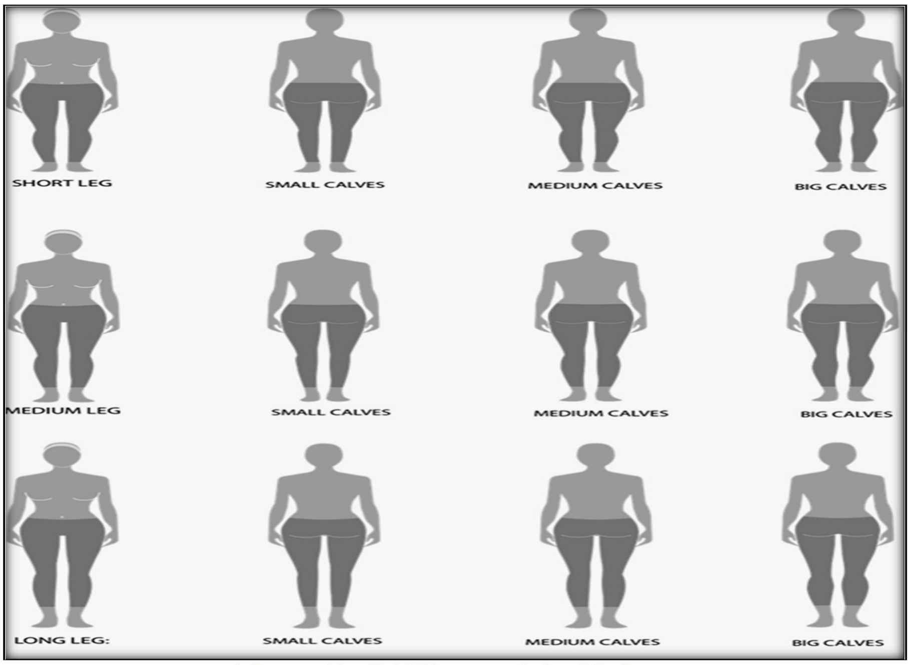

Figure 12: Calf Shape and size Variety.

This-unfunded concise-study was preliminary, by nature; its-results, are largely, relatively-positive, providing a-good-starting-point, for further and much-deeper-study, on the-same. Next-logical-step, would be a-detailed-design, which can-be-generated, using 3D-solid-modeling CAD-programs, such-as SolidWorks. CAD-models can-be created, for components and assemblies, to-check, for interference, before any-physical parts are made.

Also, the-Finite-Element-Analysis/Method (FEA/FEM) can-be used, to-conduct stress-strain investigations. The-most-characteristic-case is to-use FEA to-understand what stress will-develop, in-a-part, under certain-loading-conditions. Besides, AUTODESK Simulation-Mechanical, can-be-used, to-perform Stress-Strain-analyses; the-same-package can-be-also-used to-perform heat-transfer-modeling.

In-addition, final trade-off of performances-test (see Masctelli, 2000), and **FMEA-**tests should-be conducted, as every-product has some-possible-failure-point, and it-is important to-identify such failure point(s) and the-subsequent-effect(s). Moreover, a-particular-component-failure is often identified, during the-use-ability-testing-process, meaning that only that-component should-be redesigned, and not the entire product (see Starovoytova, 2018).

The-current (conceptual)-design is rather-uncomplicated, hence, EDWDM was considered to-be sufficient, during selection of best-design-alternative. At a-later (detail design-stage) additional-methods, such-as: PuCC; AHP (Analytic-Hierarchy-Process); and TRIZ (Theory of Inventive-Problem-Solving) should-be-applied (see Renzi *et al.,* 2017; Starovoytova , 2015; Starovoytova *et al.,* 2015; Mansor *et al.,* 2013; 2014).

Moreover, it-is a-standard-procedure to-analyze the-marketing-aspect of any-newly-designed-device, and hence, it-is recommended.

Lastly, reviewing the-British-Standard for Workplace-First-Aid BS8599-1, for Professional-First- Aid-Kits (Sports), it was exposed that there is absolutely-nothing that it provided, for the-relieve of EAMC, under such-standard. In-particular, according to-the-standard, a-Standard-Sports First-Aid-Kit should provide the-treatment-solutions for the-following-conditions: Bleeding, Asthmatic-attack, Broken-bone, Concussion, Diabetic-attack, Eye-injury, Fractured-bone, Hypothermia, Shock, Soft-tissue injury, and in addition, it should contain a-tweezers and a-paramedic-shears. Taking into-consideration that EAMC is rather-common, in-sports, the-study, therefore, recommends to-include into-first-aid Sport-kit, a-device, which could help in-managing EAMC, such-as for example, the-massaging-device, designed by this-study.

5. Conclusions and Recommendations.

The-current-study revealed that the-patho-physiology, causing EAMC, is most-likely multi-factorial and complex.

Besides, this-unfunded concise-study was preliminary, by nature; its-results, are largely, relatively positive, providing a-good-starting-point, for further and much-deeper-study, on the-same. The-study, hence, further recommends:

i) More-advanced-methods, such-as PuCC; AHP, and TRIZ should be considered in-selection of the-best design-alternative;
ii) Further-studies, to-optimize the-dimensions of the-device, to-accommodate different-shapes of calf-muscles;

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iii) To-conduct prototyping and a-detail-design;
iv) Additional-tests, such-as FEA/FEM and the-use-ability-testing should be incorporated;
v) Comprehensive materials-selection should be detailed *via* Ashby-charts; and
vi) To-analyze the-marketing-aspect of the-final-device.

Lastly, the-author would-like-to-emphasize that there is absolutely-nothing that can ever-be-perfect that is made by man, especially when it-is at its-initial-stages, and, thus, the-author would-like-to-welcome constructive expert-criticism from the-readers (*if any*).

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