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Draft Research Proposal

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Priming the Catapult: A novel method for retraining gait using cutaneous feedback, tendon-muscle springs and passive dynamic rotation to enhance spinal reflexes.

1. Introduction and Research Background

Although the gravity-dependence of the nervous system is well known to space researchers[1], the significance of the related mechanisms for our terrestrial wellbeing is not widely appreciated. This is surprising, given that the very same pathological symptoms astronauts experience due to gravity deprivation readily play out here on Earth[2], albeit over a longer time frame.

The hypothesis at the heart of this proposal postulates an overlooked – yet critical – cause of many musculoskeletal and neurological conditions: Gravity deprivation due to inefficient body-use[3,4] and poor rotational dynamics[5]. Such an idea would be impossible if the body were composed solely of homogenous material, offering no potential for differential acceleration. Since this is not the case, Einstein's equivalence principle applies, whereby gravity acting on a stationary link in a kinetic chain is equivalent to the acceleration of the link when it is internally displaced[6]. The displacement would be initiated by a relaxation impulse travelling through the body as a wave, creating a ripple in the chain.

In this way, a differential (or gradient) is created between gravity acting externally on the body – consistent for all terrestrial humanity – and gravity acting internally i.e. within and between specific functional units. To draw an analogy with electromagnetic theory, a weaker differential would imply low permeability i.e. reduced internal penetration of the gravitational field. For example, 'pushing off' using co-contraction directly against gravity[7] blocks internal acceleration, reducing force penetration. Conversely, 'pulling on' via flexor relaxation[8] counters the uplift and increases top-down internal acceleration, allowing gravity to be stored inside the body for reflexive release as kinetic energy[9].

Human locomotion in microgravity and underwater offers up further evidence in support of the central hypothesis. When deprived of gravity, the body not only behaves like a homogenous block; it also experiences lower joint torques[10], which reduce axial rotation. Fittingly, this corresponds to an exaggerated version of how nearly all of us walk on Earth[11]. That is, stifling angular momentum and squandering large quantities of energy to lever our body up directly against gravity, as if it were 'dead meat' and limited to motion in two dimensions. The million dollar question: Why is this the case, when it is known[12,13,14,15] that humans are capable of much more efficient, gravity-friendly movement?

The reason could be partly neurological. A prominent researcher has found that each hemisphere engenders a distinct, reciprocal mode of functioning[16]. When the left hemisphere is dominant, space and time are 'flattened' into 2D (e.g. rectilinear motion), whereas with right hemisphere dominance, perception and action become more three-dimensional (e.g. curvilinear motion). Additionally, given that only the right parietal lobe contains a whole-body image[17], it is reasonable to infer that only movement under right hemisphere supervision could achieve a holistic balance of forces. When this '3D mode' is triggered, the postural dynamics would have the potential to be equally effective across all three planes of motion[18] and thus enable consistent interaction with the gravitational field.

When walking in 3D, factors such as weight distribution and spring loading become instruments of propulsion, especially when highly permeable force channels and the elastic potential of muscle-tendon units[19,20] are fully exploited. The resultant rotational dynamism[21] allows the body, spine and brain to consistently tap into gravity as a power field. This suggests a starring role for sensory feedback[22], taking centre stage as the driving force for pattern generation and balance control[23,24].

2. Research Significance and Questions

The combined lessons from fourteen years of primary research and practice as well as independent studies relating to the neuromechanics of motion including Passive Dynamic principles[25], robotics[26], African load-carrying[27], Spinal Engine theory[28], microgravity effects[29], early motor learning[30], General Relativity implications and hemispheric differences[31] have led to the following conclusion:

Our common concept of human locomotion is faulty and gravity can indeed be harnessed to control and power movement, with great efficacy. If this is true, it makes sense to investigate the price we are paying for adopting precisely the opposite strategy. At the same time, the mechanisms and effects concerning gravity-driven sensorimotor loops and flexion-extension cycles should be far more extensively explored.

Despite the many millions of dollars poured into medical research, musculoskeletal[32] and neurological[33] conditions are profilerating rapidly among the general population, leading to premature and widespread forms of disability. Clearly, we are missing one or more of the key causative factors involved. The author is not alone in suggesting that a relative disregard for the mechanical basis of disease could be a major contributor[34]. However, mechanobiologists[35] and others have yet to fully appreciate the significance of variable interaction with the gravitational field and its effect on wellbeing. This may be because the life sciences have suffered a particularly long hangover from Newtonian physics and have not yet adjusted to the implications of General Relativity for internal motion and physiological function.

Now that the rationale has been sufficiently explained, the specifics of the proposal are as follows:

The author wishes to develop and test a new treadmill-based method for retraining gait under laboratory conditions, according to his understanding of the neuromechanisms enabling human locomotion. The treadmill would include novel console design features in order to passive-dynamically modify the user's internal acceleration and thus local gravitational forces. It would also allow the user to maximise cutaneous[36] (and other) sensory feedback. The techniques, experimental setup[37] and provisional results[38,39] are presented in eight videos, all referenced in this proposal.

During the research, the author intends to gain more clarity regarding the following questions:

- *Is the gait retraining concept valid from both a theoretical and practical perspective?*
- *If so, what are the most promising and important real-world applications?*
- *What are the design, engineering, testing and regulatory requirements for each application?*
- *Which application is the most viable and has the strongest commercial potential?*

3. Proposed Research Plan

The research would begin with a literature review in order to build upon and synthesise the existing secondary sources (sampled overleaf). This will also be used to further develop/refine the author's conceptual models and frameworks, which will be validated over the course of the project and used to evaluate any data collected within the correct context. In parallel, the experimental setup including console(s), instrumentation etc will need to be further researched – and relevant sources of expertise consulted – in order to ensure effective design, construction and testing prior to deployment.

The primary research sources will revolve around data gathered via the treadmill-based experimental setup. This would be either from in-built instrumentation or from additional devices, such as strain gauges, portable motion capture technology, force-sensitive insoles, belt velocity fluctuation sensors[40] etc. In addition, participant interviews and anecdotal real-time feedback will be extensively used. The selection of participants, testing protocol etc is a critical part of the process would need to overlap with the above. User selection will also require research/consultation in order to categorise suitable user groups in terms of urgency and/or importance of need, type and stage of pathology and so on.

4. References

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