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Review Article

The Fallacy of Ascribing Proprioception to Proprioceptors

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Abstract

Proprioception, considered as obtaining information about one's own action, does not necessarily depend on proprioceptors. For example, the classical misconception of the "pattern" of contacts on the skin comes from the assumption that the skin is anatomically projected to the brain's cortex by neurons and that each neuron has its own sensation. At the knee joint, perceptual systems are active sets of organs designed to reach equilibrium through synergies-the combined action that the skin and the joints are both projected to the somatosensory area of the cortex, to the same area, and the joints cannot even be imagined delivering a flat map to the brain. Under these assumptions, we are particularly interested in how the reactive mechanism of the body works to the ground reaction force (GRF) during the stance phase utilizing the knee proprioceptive system.

We have outlined the components of the knee proprioceptive system. This study aims to show that both action and awareness at the knee joint can be studied scientifically. This rests on the extension of this study's distinction between two modes of activity: exploratory and performatory. This is because the knee joints are exploratory sense organs, but they are also performative motor organs; that is to say, the equipment for feeling is anatomically the same as the equipment for doing.

Keywords: Somatosensory Cortex; Mechanoreceptors; Instantaneous knee axis (IKA); The knee complex in Involution; The Knee Proprioceptive System; Osteoarthritis (OA) of the knee

Introduction

Body´s Reacting Mechanisms

For half a century - since Sherrington (1906) - the eyes, ears, nose, mouth, and skin have been classified as exteroceptors; the end organs in muscles, joints, and the inner ear have been called proprioceptors [1]; Accordingly, awareness of our own motion, weight and position is obtained from within the body itself rather than from the outside world. It is accomplished by means of sensations arising in certain nerve end-organs.

Mabel Todd, the author of the book "the thinking body," expressed that the body possesses the power of reacting to gravity, inertia, and momentum, the primary forces of the physical world, by means of that part of the nervous system known as proprioceptive, or "perceiving of self," as distinguished from the exteroceptive mechanisms by which the outer world is perceived [2]. Proprioception, considered as obtaining information about one's own action, does not necessarily depend on proprioceptors, and exteroception, considered as obtaining information about extrinsic events, does not necessarily depend on exteroceptors [3,4].

Sherrington's contribution to the study of behavior was to experimentally show how animals' posture and locomotion were governed by auto stimulation or the circular action of the nervous system. He demonstrated it at the level of reflexes, the actions necessary for resisting gravity, maintaining equilibrium, and walking

[3]. However, Gibson also suggested that although in 1900, Sherrington probably failed to realize that the same circular action also operates at higher levels, as in the visual/haptic control of locomotion and the control of skilled manipulation.

Motivated by Gibson's proposition, and this study addresses the higher order of reflexes the action necessary for resisting GRF to maintain an equilibrium of the knee movement employing the knee proprioceptive system. Before selecting a specific method for assessing proprioception, it is essential to consider which component of proprioception is to be assessed [5]. In walking, it is helpful to remember that gravity affects our action in two ways: in down-thrust and equal up-thrust due to resistance by the ground to the pressure of each foot, that is, the ground reaction force (GRF). The study showed that the rule of the visual/haptic control of locomotion is not that sensations from the skin and the joints are blended or fused when they occur together but that the receptors then combine in one system to register one kind of invariant stimulus information [6]. Active touch and movement refer to what is ordinarily called touching-variations in skin stimulation caused by surfaces are altered together by motor activity variations. This fact is worth noting because it is often neglected that locomotion and its surfaces form an inseparable pair [7].

In light of this latter view, it is insufficient to consider proprioception just as a cumulative neural input to the central nervous system (CNS) from the mechanoreceptors located in muscles, joints, and the skin, and it is inappropriate to interpret either passive movement detection without muscle activation or a measure of reflex muscle activation as overall proprioceptive ability [8]. But the fact is that the skin and the joints are *both* projected to the somesthetic area of the cortex [9] to the same location, and the joints cannot even be imagined to deliver a flat map to the brain. Bone space and skin space are all of a piece [3]. The neural input with covariation differs from either of the two without covariation [6].

Knee Complex in Involution as a Proprioceptive System

The knee proprioceptive system's action reception components have been described [7,10]. A knee complex is determined from a combination of the projectively dependent six action components; likewise, the knee complex is determined by the action screw five-system from six constraints representing the intra-articular structures of the 1 F knee as the unique instantaneous knee axis (IKA) [11]. Thus, the knee complex includes forces acting along with anterior cruciate ligaments (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), lateral collateral ligament (LCL), and articular cartilage contact in the medial (P1) and lateral (P2) compartments [12].

The knee complex approach proposed herein was recently validated experimentally by Conconi et al. [13]. The authors calculated if all the lines of action intersect at the IKA or $ following natural knee motion to describe the knee complex invariant. The results show the mean distances between each constraint line of action, and the IKA or $ stayed below 3.4 mm and 4.5 mm for ex vivo and in vivo assessments, respectively (The results are used with the permission of Professor Michele Conconi. The video is available:

https://drive.google.com/file/d/18_YtszzT3_IvNIken5uxObj4jmSd0Zs_/view?usp=sharing).

Then in the language of freedom in motion of the knee, the 1° F knee, surrounded by its reciprocal action five-system in a unique way, forms a knee complex in involution as a higher order reflex mechanism [4,14]. Roughly speaking of how the knee proprioceptive system operates, when a foot is impressed to the ground, a reflex circle arises to replace the given GRF by force on any other action, which itself is reciprocal to the 1° F knee, and compensate for the equilibrium of 1° F knee motion. A given system of impressed forces at the knee joint will generally not be in balance: This requires fulfilling special conditions. The total virtual work of the impressed forces will usually be different from zero. In that case, the motion of the knee operates on the proprioceptive system to make up for the deficiency. The body moves in such a way that the additional inertial forces produced by the motion bring the balance up to zero [15]. In this way, knee complex in involution perceives the 1° F in an equilibrium of action of an arbitrary proprioceptive system.

To visualize the knee complex and its reciprocal connections to the IKA, one might consider the statics of a rigid body suspended in planar motion of the instantaneous rotational axis 'R'-in stable equilibrium and a parallel external force-by three taut strings (Figure 1b) [16]. The totality of all such action lines-f1, f2, f3- are projectively dependent since they form a pencil of lines in the planar rotation with the center R (Figure 1).

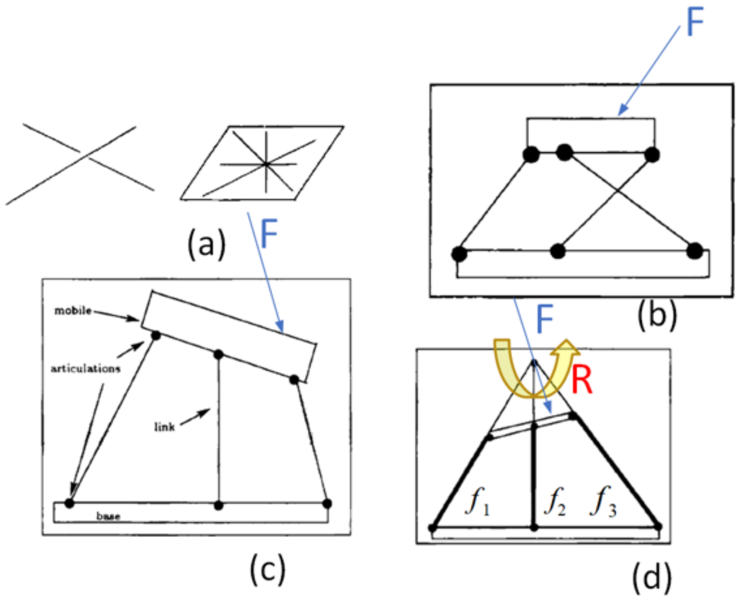

Figure 1:

(a) The union of two flat pencils having a line in common but lying-in distinct planes and with distinct centers. (b) A 2D parallel manipulator without singular configuration. (c) Singular configuration for the 2D parallel manipulator. It may be perceived that a given force, F in (c), may always be replaced by a force on any other action F in (d), which itself is reciprocal to the 1° F R. (d) A set of three action lines in space, namely the lines of action of the three balanced forces, each of which is projectivity dependent upon the other two. What makes this remarkable is that, while any two of the lines of action are enough to define the planar pencil (c), the third line of action will be found not to miss the pencil but to lie automatically and precisely upon it utilizing the auto stimulation.

The second order of reflexes laws indicates that the entrainment or coordination of shank and thigh (S, T) follows the same physical laws as the entrainment between the knee and ground (IKS, GRF) [12]. Therefore, the cross-ratio (Semple and Kneebone 1960) of the ordered pair (IKS, GRF) with respect to the ordered pair (S, T) is

$$\{(IKS, GRF);(S,T)\} = -1 \qquad (1)$$

As described, we identified the measurable second-order invariant of knee synergy and proposed it as a new view of the basis of knee proprioception by using equation (1). The knee complex approach identifies the information as a means to perceive the affordance of uniform motion transmission. To apply the described approach and identify the invariant, we characterized the shank (S) to the thigh (T) (the tibia to the femur) relative motion, i.e., the second-order invariance of the knee synergy as the instantaneous knee axis (IKA). These results were then compared with experimental data for validation as provided by the “Grand Challenge Competition to Predict In Vivo Knee Loads” as part of the Symbiosis project funded by the National Institutes of Health [17].

To test how the proposed knee proprioceptive system operates during the stance phase, we compared previously published experimental data sets [17] with our predicted datasets [18] in terms of medial and lateral contact forces. Available data included limb motion capture, fluoroscopy images, GRFs, electromyographical readings determining muscle forces, as well as medial and lateral knee contact forces derived from GRFs. Data were collected from an adult male with a right knee reconstruction (65 kg mass and 1.7 m height). When the variations in the ground contact (magnitudes and direction) were shown along with the variations of knee movement in terms of IKA, an invariant was determined uniquely by the two corresponding pairs, see equation (1) (Figure 2(b)). In this study, the IKA was determined by a linear combination of two instantaneous screw axes of the shank and thigh. As a result, the IKA is nearly reciprocal to the GRF, as indicated in a magnified inset image in Figure 2(b). In other words, the neural input with the covariation of cutaneous and articular motion is projected into the somatosensory area of the cortex to the same area as a particular invariant unit (Kim, Choi et al. 2016).

Perceiving that a force may continuously replace a given reaction force on any other action components inherent in the knee proprioceptive system, which themselves compensated with the additional inertial forces, which had been produced during the motion of the IKA. The line of this GRF must belong to the knee complex defined by the other six components of action [19]. The base of body will then take the reaction forces of the knee joint, that is, bones instead. Muscles should not be called upon to compensate for pulling the knee proprioceptive parts away from IKA in response to GRF. The muscle task is to move the bones, balance them at their medial and lateral contacts along the knee axis, and transfer their weights as directly as possible to the base. Holding them in any preconceived position results in strain. The only way to avoid this is by keeping the joints properly aligned and the muscles as free as possible to move the bones and transfer or alter their direction of movement. Antagonistic action here is between groups of muscles and muscle systems rather than between single pairs of muscles. Such result can be reached only through understanding balance and weight-thrust at the joints. Knowledge of mechanics is essential to grasp that equilibrium is a process of continuous compensation.

Moreover, this perspective defines torque-free pure forces based on the tensegrity structure Kim and Kohles 2012, [10,20,18]. Finally, it is essential to note that this configuration is a tensegrity configuration [20], as the system is pre-stressable in the absence of external forces, such as ground reaction forces during actual locomotion (Skelton and Oliveira 2009) (Figure 2).

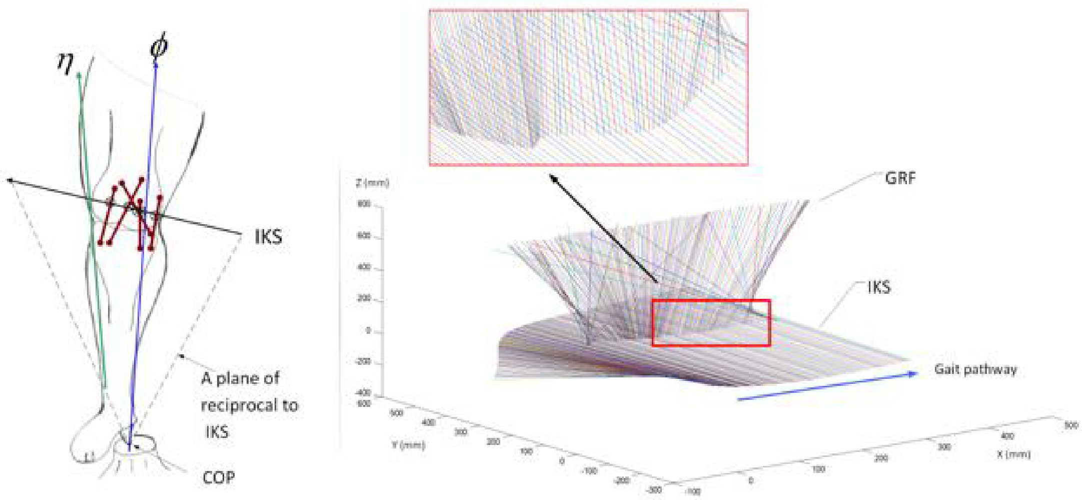

Figure 2:

Examples of haptic control of locomotion by the knee proprioceptive system

Figure 2(a): The framework for estimating responses to constraints on the knee joint (ligament forces and contact forces) is influenced by the inclusion of muscle synergy (**η**) and GRF (**φ**) relative to the center of pressure (COP). In addition, the judicious generation of the IKA for the one DOF in knee equilibrium simplifies the estimation. This figure was adapted from the original figure published previously (Kim, Veloso et al. 2013).

Figure 2(b): We found that the rule is that the ground reaction force (GRF) vector line is very close to the instantaneous knee axis (IKA). Therefore, it aligns the knee joint with the GRF such that the reaction forces are torqueless. The reaction to the GRF will then be carried by the whole structures on the body instead.

Assessing proprioception of the knee

We realize that action sensitivity or movement sensitivity does not depend on specialized receptors (Kim 2022). More specifically, Ashton-Miller et al. [14] have argued that if proprioception is only the afferent (hardware) part of the system, proprioception cannot be trained because there is no capacity to train a signal. In contrast, a recent systematic review by Witchalls et al. [21] has demonstrated that proprioception as a measure of the neuromuscular response to a stimulus must involve sensory input, central processing, and motor output in a closed loop. In light of this latter view, it is insufficient to consider proprioception just as a cumulative neural input to the central nervous system (CNS) from the mechanoreceptors located in muscles, joints, and the skin, and it is inappropriate to interpret either passive movement detection without muscle activation or a measure of reflex muscle activation as overall proprioceptive ability (Han, Waddington et al. 2016). The eyes, ears, nose, mouth, and skin can orient, explore, and investigate. When thus active, they are neither passive senses nor channels of sensory quality but ways of paying attention to whatever is constant in the changing stimulation [3].

The trouble with the assumption that second-order haptic invariants specify a high level of reflexes is that experimenters, accustomed to working in the laboratory with low-order stimulus variables, cannot think of a way to measure them. How can they hope to isolate and control an invariant of haptic structure to apply it to an observer if they cannot quantify it? First, they should not hope to apply an invariant to an observer, only to make it available, for it is not a stimulus. And second, they do not have to quantify an invariant to apply numbers to it, but only to give it an exact mathematical description like the equation (1) so that other experimenters can make it available to their observers [22].

The role of proprioception in daily activities, exercise, and sports has been extensively investigated using different techniques. Yet, the proprioceptive mechanisms underlying nonsurgical treatment for patients with knee osteoarthritis control are still unclear. The first peak of the external knee abduction moment (KAM) is often used as a surrogate measure of the medial compartment loading. It has been correlated with pain and progression of knee osteoarthritis (O.A.) [23, 24]. However, this study [19] puts an alternative measure on how O.A. patients are likely to develop overloaded medial compartments during walking with their inappropriate reflexes due to slight projection of the external load onto the constraints at the knee. High loads incur from the impaired condition of this knee proprioceptive system. Suppose muscles are called upon to lift and hold reaction forces unnecessarily instead of moving bones in a balanced relationship. In that case, such action violates their relationship with the nervous system, as the reflex circle that arises is not designed to induce the appropriate reflexes. Holding parts in fixed and strained relations impede the circular action of the nervous system, and the resultant congestion of one part and the defrauding of another can work havoc throughout the system, operating overloaded in the medial compartment. The conscious direction of a moving function rather than a holding function should emphasize where bones, muscles, and ligaments are concerned since man presents a dynamic problem.

Conclusion

To secure conscious control of balance in the bony structure of the human knee, it would be better to understand its mechanical design and then trust the long-established automatic machinery of the neuromuscular system to make the necessary space-time adjustments. The knee's movements are neither triggered nor commanded but controlled. Moreover, they are controlled not by the brain but by information, that is, by touching oneself on the surface. The current neuromuscular modeling approach for knee biomechanics seems to lead to the idea of a human object as a highly complex object of the physical world. This way of thinking neglects the fact that the human–object is surrounded in a special way [19], that control lies in the human–surface system, but this automatic process is interfered with whenever we attempt to force into a new position any particular part without reference to the pattern of the whole as exemplified in the knee complex in involution, ignoring the mutuality of animal and surface (Gibson 1986).

The muscle task is to move the bones, balance them at constraints in the joint such that no work results along the axis of 1° F knee, and transfer their weights as directly as possible. They should be used for this purpose and not the work assigned to the bones.

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Conflicts of Interest

No conflicts of interest.

References

1. Sherrington C (1952) The integrative action of the nervous system CUP Archive.
2. Todd ME (1937) The Thinking Body A Study of the Balancing Forces of Dynamic Man, PB Hoeber, Incorporated.
3. Gibson JJ (1966) The senses considered as perceptual systems. Boston Houghton.
4. Kim W (2020) The Knee Proprioception as Patient-Dependent Outcome Measures within Surgical and Nonsurgical Interventions. Proprioception IntechOpen.
5. Han J, G Waddington, R Adams, J Anson, Y Liu (2016) Assessing proprioception: What do you really want to know? Response to Krewer et al. Journal of sport and health science 5(1): 93 -94.
6. Kim W (2022) Study about Rules for the Haptic Control of Locomotion. Research Developments in Science and Technology Vol. 1: 1-5.
7. Kim W, D Araujo, SS Kohles, SG Kim HH Alvarez Sanchez (2021) Affordance-Based Surgical Design Methods Considering Biomechanical Artifacts. Ecological Psychology 33(1): 57-71.
8. Han J, G Waddington, R Adams, J Anson, Y Liu (2016) Assessing proprioception: a critical review of methods. Journal of Sport and Health Science 5(1): 80-90.
9. Bushnell M, G Duncan, R Hofbauer, B Ha, JI Chen, et al. (1999) Pain perception: is there a role for primary somatosensory cortex? Proceedings of the National Academy of Sciences 96(14): 7705-7709.
10. Kim W, A Veloso, J Tan, C Andrade (2010) A Reciprocal Connection at Knee Joint. ASME 2010 Summer Bioengineering Conference, Naples FL.
11. Hunt K H (1990) Kinematic geometry of mechanism. Oxford Clarendon Press.
12. Kim W, D Araujo, SS Kohles, SG Kim HH Alvarez Sanchez (2020) Affordance-Based Surgical Design Methods Considering Biomechanical Artifacts Ecological Psychology: 1-15.
13. Conconi M, N Sancisi, V Parenti-Castelli (2019) The geometrical arrangement of knee constraints that makes natural motion possible Theoretical and experimental analysis. Journal of biomechanical engineering 141(5): 051001.
14. Wojtys EM, JA Ashton-Miller, D Fry-Welch, LJ Huston (2001) Can proprioception really be improved by exercises?
15. Lanczos C (2012) The variational principles of mechanics Courier Corporation.
16. Merlet J P (1989) Singular configurations of parallel manipulators and Grassmann geometry The international journal of robotics research 8(5): 45-56.
17. Fregly BJ, TF Besier, DG Lloyd, SL Delp, SA Banks, et al. (2012). Grand challenge competition to predict in vivo knee loads. Journal of Orthopaedic Research 30(4): 503-513.
18. Kim W, A P Veloso, D Araújo, V Vleck, F João (2013) An informational framework to predict reaction of constraints using a reciprocally connected knee model Computer Methods in Biomechanics and Biomedical Engineering 18(1): 78-89.
19. Kim W, E A Vela (2022) Freedom in Osteoarthritis of the Knee. Applied Sciences 12(2): 839.
20. Kim W, EA Vela (2021) A Tensional Network in the Knee. Biomedical Journal of Scientific & Technical Research 40(2): 32073-32078.
21. Witchalls J, P Blanch, G Waddington, R Adams (2012) Intrinsic functional deficits associated with increased risk of ankle injuries: a systematic review with meta-analysis. British journal of sports medicine 46(7): 515-523.

22. Gibson JJ (1979) The ecological approach to visual perception Houghton Mifflin.

23. Sharma L, DE Hurwitz, EJ Thonar, JA Sum, ME Lenz, et al. (1998) Knee adduction moment, serum hyaluronan level, and disease severity in medial tibiofemoral osteoarthritis. Arthritis Rheum 41(7): 1233-1240.

24. Andriacchi TP, TM Griffin, RF Loeser, CR Chu, EM Roos, et al. (2020) Bridging Disciplines as a pathway to Finding New Solutions for Osteoarthritis a collaborative program presented at the 2019 Orthopaedic Research Society and the Osteoarthritis Research Society International. Osteoarthritis and Cartilage Open 2(1): 100026.

25. Gibson JJ (1986) The Ecological Approach to Visual Perception Lawrence Erlbaum Associates.

26. Kim W (2021) A Critical Study on the Duality of Functional Knee Axes and Foot Contact. Research Trends and Challenges in Medical Science Vol. 8: 62-71.

27. Kim W, Y Choi, HG Lee (2016) The Duality of Knee Functional Axes and Foot Contact. Journal of Functional Morphology and Kinesiology 1(4): 387-395.

28. Semple JG, GT Kneebone (1960) Algebraic Projective Geometry Clarendon Press.