核心稳定性研究历史与现状

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摘 要： 核心稳定性是一个广泛应用于包括健康和医学领域在内的多领域的常见术语，科学文献中有关核心稳定性定义的表述各不相同。通过对“核心”的位置、核心稳定性中的稳定性的定义、核心稳定性的构成的分析，确定人体“核心”的位置，探讨“核心稳定性”中的“稳定性”的内涵，分析核心稳定性的生物力学原理。

关键词： 核心稳定性；位置；定义；构成

中图分类号：G804.6　　文献标志码：A　　文章编号：1006-1207(2011)05-0001-09

Historical and Current Understanding of Core Stability

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Abstract: Core stability is a term frequently used in many fields including health and medical areas. The definitions of core stability in different scientific documents are not the same. Through the analysis of the position of core, the definition of stability in core stability and the composition of core stability, the article tries to define the position of core in human body, discuss the connotion of stability in core stability and analyze the biomechanical principles of core stability.

Key words: core stability; position; definition; composition

核心稳定性是一个广泛应用于包括健康和医学领域在内的多领域的常见术语。不论是用来预测工人发生下背部损伤的风险（luoto 等人，1995 年），还是用来探索如何提高高尔夫运动水平（Tsai 等人，2004），科学文献中有关核心稳定性定义的表述各不相同。本文主要目的是进一步加深对人体“核心”位置的理解，探讨“核心稳定性”中的“稳定性”的内涵，分析核心稳定性的生物力学原理。本文将不涉及有关核心稳定性的测试方法以及它与运动能力和伤病的关系。

1 “核心”的位置

20 世纪 60 年代至 70 年代，研究人员开始研究人体（或者说人体躯干）中间部位的稳定性。莫里斯（Morris，1961）等人是最早一批把人体的躯干、胸部和腹部作为腰椎稳定性要素开展研究的研究者之一。此后，阿斯普登（Aspden）于 1989 年引用了一个脊柱类比作一个弓型结构的数学模型。这个数学模型展示了人体姿态对于脊柱稳定性的重要作用。通过使用这个数学模型，阿斯普登观察到，早先有关椎间压力的测量结果被高估了。如今对躯干稳定性的研究涉及多个解剖结构，不仅仅局限于研究腰椎。所谓的“核心”可以包括连接人体上肢与下肢之间的所有结构。下面将详细讨论核心的解剖结构，然后探讨其功能。

比利斯（Bliss）与蒂普尔（Tepple）于 2005 年对“核心”的解剖结构进行了简单的阐述。他们认为，“核心”是指围绕在腰椎和骨盆周围的肌肉组织，这些肌肉包括腹肌、臀肌、竖脊肌、髋关节外展肌、外旋肌和膈肌。之后，基布勒（Kibler）等人于 2006 年提出一个更详细的关

收稿日期：2011-08-15

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Introduction

Core stability is a common term used within several industries including the health and medical professions. Whether it is used to predict the risk of low back injury among workers (Luoto, et al., 1995) or to determine how to improve one’s golf game (Tsai, et al., 2004), the definition of core stability has been known to vary throughout the scientific literature. The objectives of this review is to provide a clear understanding of the core’s location on the body, define stability as it relates to core stability, and to discuss the biomechanical components related to core stability. The measurements of core stability and its relations to both performance and injury are beyond the scope of this paper.

Location of the core

In the 1960 and 1970s, researchers began studying stability of the middle region of the human body, or trunk. Morris et al. (1961) were one of the first researchers who identified the trunk, thorax and abdomen, as important elements in the stability of the lumbar spine. Later, Aspden (1989) illustrated the importance of posture to spinal stability by introducing a new mathematical model in which the spine resembled an arch. Using the model, Aspden observed calculations from earlier measurements of compressive stresses on the spine were over-estimated. Today, individuals continue to study the stability of the trunk, but the stability of several anatomical structures are now included, it is not simply limited to the lumbar spine only. The so-called core may include any structures that link the upper extremities to the lower extremities. We

于“核心”的解剖学定义。其“核心”的内容包括了脊柱、髋部、盆骨、下肢近端和腹部的所有肌肉骨骼组织。与比利斯和蒂普尔相类似，基布勒和他的同事将腹部肌肉也纳入“核心”的定义中，包括腹横肌、腹内斜肌和腹外斜肌以及腹直肌和隔肌，还包括髋部肌肉（臀肌和髋部旋转肌）和骨盆。但是，与比利斯等人不同的是，他们将腰方肌、多裂肌以及胸腰部筋膜也纳入到“核心”部位，位于“核心”的后段。不仅如此，他们认为盆底肌为脊柱和躯干肌肉提供了支撑平台，也应该作为“核心”解剖结构的一部分。同时，将附着在核心部位，起动肢端运动的肌肉也纳入“核心”的范畴，包括背阔肌、斜方肌上下部、胸大肌、腘绳肌、股四头肌、髂腰肌。除了上述所提及的大部分结构外，威尔逊（willson）等人于2005年将脊柱的内在肌（竖脊肌）囊括到“核心”的范畴中来。他们认为脊柱周围的内在肌能够强化核心稳定的运动控制成分，而仅仅依靠外在的大肌群维持核心稳定性是不可能的。

综上所述，基于比利斯、蒂普尔、基布勒和他同事以及威尔逊和他的同事们的研究，建议，可以采用以下关于“核心”部位的定义：“核心”是指人体的中间部位，它通过胸部和腰髋部向下连接下肢，向上连接上肢和头颈部。这个定义在解剖学上涵盖了该区域中所有的肌肉和神经组织，在功能上强调简捷、有效。

2 核心稳定性中的稳定性的定义

在科学文献中，稳定性有很多含义。研究人体运动和生理核心稳定性中的稳定性亦不例外。例如，有几项关于人体步态稳定性的研究（布奇和乌尔里希，2004年；科威尔和牛顿，2004年；巴哈特等人，2006年）和心脏节律稳定性的研究（斯坦因等人，1995年；莱哲和西维尔奇，1998年；马利克，1998年）等。不仅如此，稳定性可划分为动态稳定性和静态稳定性。正如里弗斯等人于2007年所说：“研究稳定性要根据研究的人体系统和需要完成的任务而定。”本文将讨论在不同的解剖学结构和关节中，如何定义这些结构和关节的稳定性，然后再应用到核心稳定性上来。

稳定性、稳定以及不稳定性等词汇曾被用来描述一些不同的身体部位（例如踝关节、膝关节、肩关节以及腰椎）。威克斯特等人于2006年定义膝关节和踝关节的动态稳定性为：“在高强度运动中能够保持正常活动的能力而不失控”。又如上肢，鲍尔萨等人于2008年描述了肩关节的动态稳定和静态稳定。对于盂肱关节，他们将静态稳定性定义为：“被动性结构保持肱骨头在关节盂中不发生位移的能力”，而将动态稳定性定义为“肩袖和肩胛骨稳定肌主动保持肱骨头在关节窝内的能力”。鲍尔萨和他的同事使用半脱位或全脱位来界定被动稳定性和动态稳定性。半脱位或全脱位对于盂肱关节来说可能是一种常见的损伤，但是对于膝关节（不包括髌骨脱位）或者踝关节来说，发生这种情况几乎不可能。由此可见，不同关节的稳定性的定义也不尽相同，或在描述身体不同部位的稳定性时，需要考虑身体的不同部位。稳定性这个词，不单单可以用来描述肢体关节，还可以用来描述脊柱和骨盆。

当研究脊柱稳定性的时候，研究者必须要确定是研究动态稳定性还是静态稳定性，然后再观察椎骨的运动形式。与肩部很相似，在研究脊柱的稳定性时，研究者必须判断一个

will discuss studies that attempt to elaborate on the anatomical makeup of the core first and then the functions later in the paper.

Bliss and Teeple (2005) introduced a simple description of the anatomical structures which form the core. They stated the core included the musculature that surrounded the lumbopelvic region. These muscles included the abdominals, the gluteals, the paraspinals, the hip abductors and external rotators, and the diaphragm. Kibler et al. (2006) later proposed a more detailed definition of the core's anatomy. Their definition included all the musculoskeletal structures of the spine, hips, pelvis, proximal lower limb, and abdomen. Like Bliss and Teeple Kibler and colleagues included the abdominal muscles: transverse abdominus, internal and external obliques, and rectus abdominus, as well as the diaphragm, and the muscles of the hips (glutei, hip rotators) and pelvis. Unlike Bliss and Teeple, Kibler and coworkers included the quadratus lumborum, the multifidi, and the thoracolumbar fascia as part of the posterior segment of the core. Furthermore, they stated the pelvic floor muscles should be included in the anatomy of the core since they helped to provide a base of support for the spine and trunk muscles. Kibler and company also included the prime movers of the extremities, latissimus dorsi, upper and lower trapezium, pectoralis major, hamstrings, quadriceps, and the iliopsaos, since they attached to the core. In addition to most of the structures mentioned above, Willson et al. (2005) included the intrinsic muscles of the spine (erector spinae) to their description of the core. They stated that the intrinsic muscles helped enhance the motor control components of the core stability, which would not be possible if one was only to include the large global muscles.

We propose the following summary of the location of the core based on Bliss and Teeple (2005), Kibler and coworkers (2006), and Willson and associates (2005). The core is the mid-section of the body that links the lower extremities to head, neck, and upper extremities through the thorax and lumbar-pelvic regions. It consists of all the muscular and neurological structures that make this linkage anatomically possible, while functionally effective and efficient.

Definition of Stability as Applied to the Core

The term stability has many definitions in scientific literature. This is certainly the case when studying human movement and physiology. For instance, there are several studies on the stability of the human gait pattern (Buzzi and Ulrich, 2004; Cromwell and Newton, 2004; Bhatt, et al., 2006) and cardiac rhythm stability (Stein, et al., 1995; Leger and Thivierge, 1998; Malik, 1998). Furthermore, there are different classifications of stability including dynamic stability and static stability. As Reeves et al. (2007) so well stated, “stability depends on the system and the task being performed.” We will first discuss how stability has been defined and used in different anatomical structures and joints, then onto its applications in core stability.

The terms stability, stable, or instability have been used to describe several different body parts such as the ankle, knee, shoulder,

外在的干扰是否导致了椎体位移超过正常生理活动范围（里弗斯等人，2007 年）。卢卡斯（Lucus）和布雷斯勒（Bresler）于1961 年首次进行了静态脊柱稳定性的测量，他们在进行单独的胸腰段椎体测试时，发现椎体20 N的压力作用下发生了弯曲变形。随后，克里希克（Crisco）等人于1992年测试出单独的腰椎在平均压力负荷大于88 N时会变得不稳定。上述测试帮助研究人员得以确定脊柱的静态稳定性的概念，即伯格马克（Bergmark）于1989年定义的静态稳定性是指负重的人体结构能够保持平衡性的能力。如果没有稳定性，那么某种细小的改变平衡性的因素都会对结构产生"崩溃性"的后果。这样的稳定性的定义不能准确的描述核心稳定性，例如霍莱维茨基（Cholewicki）和麦克吉尔（McGill）于1996 年观察到当人在举重时，脊柱可以承受超过18 000 N的负荷。

因为脊柱是一个可以活动的系统，能够围绕3个轴进行活动，因此，有时候需要有不同的关于稳定性的定义。怀特和旁遮普（Panjabi）于1978年使用"脊柱临床稳定性"这一术语来解释脊柱是怎样承受外力的。他们定义"脊柱临床稳定性"为"脊柱在生理负荷下限制脊柱产生位移，以防止损坏或刺激脊髓或神经根，并且防止由于结构变化而致残疾或出现疼痛的能力"。随后，霍莱维茨基（Cholewicki）和麦克吉尔（McGill）于1996 年为研究脊柱的动态稳定性做出了贡献。通过使用一个腰椎模型，他们观察到腰椎在高负荷活动中稳定性增强，而在低负荷活动中稳定性降低。他们的观察实验推翻了原来的假设，即腰椎的稳定性是一成不变的。而且，他们的观测直接引出了"显著稳定"这一概念，即麦克吉尔等人于2003年提出的个体必须通过一个低强度但持续的肌肉活动来保持一个显著的稳定性。

霍奇斯于（Hodges）2004 年进行了腰盆骨稳定性的复合模型的研究，可能是首次就核心稳定性的概念所进行的研究。霍奇斯定义"腰盆骨稳定性"为："在实现某种身体功能的背景下，控制静态姿势的一种动态过程，但这种控制的动态过程允许躯干在可控范围内运动"。霍奇斯还描述了腰盆骨稳定性的3种相互依存的层次水平：全身平衡性控制、腰骨盆方向性控制和椎体间控制。当躯干为了移动（人体）身体重心（center of mass-COM）而重新定位时，全身平衡性控制是非常重要的。霍奇斯特别指出，如果不能做到全身平衡性控制，便也无法保持腰盆骨方向性控制和椎体间控制。腰盆骨方向性控制主要是在人体运动中维持脊柱和骨盆的弯曲度和姿态，这是极其重要的。因为，如果不能保持控制，那么在运动中椎体便会发生挤压和变形情况。椎体间控制能力主要是控制每个椎体的平移和旋转。这种能力并不是独立于腰盆骨方向性控制水平，也有可能发生脊柱节段性的挤压和变形。

随后，与2004 年霍奇斯定义核心稳定性相比，学者们对核心稳定性的定义进行了简单改动。比利斯和蒂普尔于2005 年定义脊椎的动态稳定为：当进行某种动作时，利用肌肉的强度与耐力来控制脊椎保持平衡位置，防止改变平衡时的脊椎姿态的能力。威尔逊等人于2005 年定义核心稳定性为：腰盆骨－髋部复合体能够对抗外界干扰而维持平衡的能力，且没有造成椎体的挤压和变形。最近，基布雷尔（Kibler）等人于2006 年定义核心稳定性为：在动力链活

and the lumbar spine. Wikstrom, et al. (2006) defined the dynamic stability of the knee and ankle as "the ability to maintain normal movement patterns while performing high level activities without unwanted episodes of giving way." Looking at the upper extremity, Borsa, et al. (2008) described both a static and dynamic stability of the shoulder complex. At the glenohumeral joint, they defined passive stability as the ability of the passive structures to resist the displacement of the humeral head from the glenoid, while dynamic stability is the ability of the rotator cuff and scapular stabilizing muscles to maintain the humeral head centered on the glenoid fossa. Borsa and company used the end result of a subluxation or dislocation to define both passive and dynamic stability of the shoulder. A subluxation or dislocation may be a common injury of the glenohumeral joint, but it is highly unlikely in the knee (not including a patellar dislocation) or ankle. This helps illustrate that the definition of stability may differ from joint to joint, or a different description of stability may be required when referring to different locations on the body. The term stability, in addition to its use in joints of the extremities, it has also been applied to the spine and pelvis.

In studying the stability of the spine one must determine if they are studying static or dynamic stability and then observe the behavior of the vertebrae. Much like the shoulder, when studying the stability of the spine, one must determine if a perturbation results in the displacement of the vertebrae past its physiological range (Reeves, et al., 2007). Lucus and Bresler (1961) might have been the first to test the concept of static spinal stability when they observed that the isolated thoracolumbar spine would buckle under a compress load of 20 N. Crisco, et al. (1992) later isolated the lumbar spine and calculated an average compress load of 88 N, before the spine would become unstable. These experiments helped to demonstrate the concept of static stability of the spine, which is defined as the ability of a loaded structure to maintain static equilibrium (Bergmark, 1989). If stability were not upheld, then any small changes in equilibrium would cause the structure to "collapse" (Bergmark, 1989). This definition of stability may not be accurate to describe core stability, since the spine has been observed to accept loads up to18000 N during power lifting (Cholewicki and McGill, 1996).

Since the spine is a mobile system with the ability to change position in three axes, a different definition of stability is needed at times. White and Panjabi (1978) used the term "clinical stability of the spine" to explain how the spine accepted loads. They define "clinical stability"as the "ability of the spine under physiological loads to limit patterns of displacement so as not to damage or irritate the spinal cord or nerve roots and, in addition, to prevent incapacitating deformity or pain due to structural change". Further contributing to the notion of dynamic stability of the spine, Cholewicki and McGill (1996) observed the stability of the lumbar spine, using a lumbar spine model, increased during high demanding tasks and decreased during low demanding tasks. Their observations did not support the hypothesis that the spine main-

动中，在盆骨和腿部以上控制躯干的位置和动作，产生、传递、控制力量和动作至下肢的能力。

稳定性在不同的人体系统和动作形式中有不同的定义。此外，因为不论是在预防伤病还是提高运动表现中，核心稳定性都相当重要。所以，当研究核心稳定性的时候，需要一个精确的核心稳定性的定义。因此，我们建议核心稳定性的定义为：为了维持核心的解剖学完整性，能够对抗外界的机械干扰，并能支撑核心乃至整个人体的功能性的能力 。

3 核心稳定性的构成

旁遮普于1992年首次引入了3个相互关联的子系统，如果有受伤或受损的情况，所有系统能够彼此补偿，这样就形成了脊柱的稳定系统。3个子系统包括被动肌肉骨骼系统、主动肌肉骨骼系统、神经性反馈系统（也称为神经控制系统）。

3.1 被动成分

奥沙利文（O'Sullivan）等人于1997年提出，核心稳定性的被动成分包括椎骨、椎间盘、椎骨关节突关节和脊柱的韧带。单独的被动结构是非常不稳定的，仅仅20 N的外力便可以使腰胸段椎体出现弯曲变形（卢卡斯和布雷斯勒，1961年）；88 N的外力可以使得孤立的腰椎弯曲变形（克里斯科等人，1992年）。旁遮普赞同这种观点，他于1992年提出：被动成分在稳定性的3个成分中所起的作用最小。他认为，事实上，在平衡姿态中，被动成分几乎没有起任何作用，仅仅处在运动范围的末端时，此时韧带被拉伸，能够限制脊柱的运动。不仅如此，这些韧带也可以作为神经控制成分（将在下文予以讨论），因为这些韧带提供了椎体位置和运动的信息。然而，威尔逊等人于2005年提出了一致的观点：被动成分在稳定性成分中起的作用很小，是负荷作用于骨结构与软组织顺应性之间相互作用的产物。威尔士（Walsh）和洛茨（Lotz）于2004年提出：虽然一些学者声称被动成分的作用比其它成分的作用小，但是椎间盘在脊柱的稳定性中发挥着重要作用，因为椎间盘有助于人体运动过程中力量沿着椎体进行传递。此外，学者已经注意到椎间盘的损伤会造成脊椎不再稳定。萨尔（Saal）于1992年提出：腰椎间盘和小关节进行重复性的动作和受到扭转应力作用会出现退行性变化，甚至可以导致椎间关节的功能丧失，因为椎间盘负责椎体间的负荷传递。

"核心"的被动成分包括椎体、韧带、椎间盘和椎间关节。这个成分的主要作用是限制椎体运动的范围和椎体之间的力量传递。虽然被动成分的作用很小，但是被动结构损伤可以造成关节的功能丧失和不稳定。

3.2 主动成分

旁遮普于1992年提出，主动成分由环绕核心的肌肉所组成。霍奇斯于2004提出，主动系统中的肌肉具有产生力量的能力，从而有助于核心稳定性。旁遮普和霍奇斯都建议，虽然主动系统对于脊椎的稳定性具有重要意义，但它们不能单独产生功能，需要神经控制成分的参与。

威尔逊（Willson）等人于2005年详细地描述了主动成分在维持核心稳定性中的作用。他们描述了3个维持核心稳定性的机制，包括腹内压、脊柱间压力和臀部、躯干肌肉的

tains a constant level of stability. Furthermore, their observations lead to the term of significant stability, which states individuals must maintain a significant amount of stability during activities by low, yet continuous muscle activation (McGill, et al., 2003).

Hodges (2004) may have been first to study the concept of core stability in his composite model of lumbopelvic stability. Hodges defined the term lumbopelvic stability as the "dynamic process of controlling static position in the functional context, but allowing the trunk to move with control in other situations". Hodges also described three interdependent hierarchy levels of lumbopelvic stability: the control of whole-body equilibrium, control of lumbopelvic orientation, and intervertebral control. The control of whole-body equilibrium is important when the trunk is repositioned in order to move the center of mass (COM). Hodges warned that if whole-body equilibrium was not maintained, control of the lumbopelvic orientation and intervertebral control could not be maintained. Lumbopelvic orientation controled the curvature and posture of the spine and pelvis during activities. Lumbopelvic orientation was extremely important, as it was the level in which buckling could occur if not controlled. The last level in the hierarchy was intervertebral control, which controled both translation and rotation of each individual vertebra. This level was not independent of the lumbopelvic orientation and could also be exposed to segmental buckling.

Later, definitions of core stability took a simpler, but similar approach to defining stability as compared to Hodges (2004). Bliss and Teeple (2005) defined dynamic stabilization of the spine, as the ability to use muscular strength and endurance to maintain a neutral spine posture and then to control the spine beyond the neutral zone when performing activities. Willson et al. (2005) defined core stability as the ability of the lumbopelvic-hip complex to return to equilibrium following a perturbation without buckling of the vertebral column. Last, Kibler, et al. (2006) stated the ability to control the position and motion of the trunk over the pelvis and leg to produce, transfer, and control force and motion to the terminal segment during kinetic chain activities is core stability.

Stability has been defined differently, and different definitions reflect the system or movement being studied. Furthermore, when studying core stability a pinpoint definition should be developed since the concept of core stability is important in both injury prevention and physical performance. Therefore, we propose core stability is the ability to resist external mechanical perturbations in order to maintain the anatomical integrity of the core and to support the functionality of the core and the entire body.

Components of Core Stability

Panjabi (1992) was first introduced three interdependent subsystems, all capable of compensating for one another, if there is an injury or impairment, which creates the spinal stabilizing system. The three subsystems included the passive musculoskeletal subsystem, the active musculoskeletal subsystem, and the neural and feed-back subsystem, also referred to as the neural control

弹性强度。第一个机制是腹内压机制：腹内压是腹腔内部产生的压力的总和，由腹肌，即腹横肌（霍奇斯，2004年）、膈肌、盆底肌（威尔逊等人，2005年）和胸腰部筋膜（泰什等人，1987年）共同作用产生。腹内压创造了一个充满压力的腹腔，产生抵制腰椎前凸的顶点的力量，限制其运动时产生椎体节段性运动（霍奇斯和理查德森，1996），从而维持脊椎的稳定性。不仅如此，增加腹内压有可能减小脊椎间的压力负荷，从而减少了受伤的概率（达格费尔特，Daggfeldt 和索尔斯坦森，Thorstensson，2003年）。加德纳•摩尔斯（Gardner-Morse）和斯托克斯（Stokes）于1998年研究发现了主动成分的第二种机制：腹部肌肉的拮抗共激活作用，能够增加施加在脊椎上的力，从而增加脊椎的稳定性。他们同时还估算出在腹外斜肌以40%的最大努力运动时，躯干屈肌和伸肌的共激活作用能够增加最大椎体间压力负荷的21%。第三个作用机制于2005年由威尔逊等人发现并阐述，即髋部和躯干部肌肉的弹性强度。他们提出：除非躯干受到外在负荷的影响，否则，髋部和躯干肌肉实际上处于不激活的状态，而核心稳定性主要靠被动结构来维持。

主动成分在核心稳定性中扮演至关重要的角色，但是不同的肌肉起作用的方式不同。伯格马克（Bergmark）于1989年提出，人体躯干部的肌肉可以被分为两种，局部和全局肌肉系统。他描述局部肌肉为：深层肌，肌肉的起点或止点与椎体相连，其功能是控制脊椎的弯曲度，并提供矢状面和横向上的弹性强度。主要的局部肌肉包括：腹横肌、腰部多裂肌和腹内斜肌的后部纤维（奥沙利文 O'sullivan 等人，1997年）。这些肌肉，特别是腰部多裂肌，具有较大的Ⅰ型纤维的百分比（58%～69%）和较大的Ⅰ型纤维尺寸，这有助于提供支撑作用（理查森，1999年）。与局部肌肉相对应，伯格马克描述全局肌肉为：大的浅部肌肉组织，并不与脊椎直接相连。霍奇斯（Hodges）于2004年提出，全局肌肉的主要作用是产生躯干的运动，平衡来自于外部的负荷并将这些负荷由胸部向髋部传递。全局肌肉包括竖脊肌、腹内斜肌（但其后部肌纤维除外）、腹外斜肌、腹直肌和腰方肌外侧。虽然局部和全局肌肉的位置和功能不同，但是它们都非常重要，共同维护脊柱的稳定性（霍奇斯，2004年）。

3.3 神经控制成分

核心稳定性的最后一种成分是神经控制成分。旁遮普（Panjabi）于1992年提出，如果想要实现脊椎的稳定性，神经控制成分需要收集大量来自内外感受器的信息，并分析稳定的特定需求，然后激活主动成分收缩。霍奇斯（Hodges）在2004年提出：中枢神经系统不断地解读来自外周机械性感受器通过传入神经传入的信息，并将这些信息与被认为是“适当的稳定性或姿势”的信息相对比，从而以精确的方式刺激肌肉来维持脊柱的稳定性。尽管霍旁遮普和霍奇斯的观点被普遍接受，但是他们的这种观点仅仅是神经控制成分的作用机制的简单表述。Aruin 和 Latash 于1995年进一步提出，神经控制成分又分成两个子成分。第一个子成分（正反馈）是 “核心”为适应运动或干扰而进行的预调节。同时由于第一个子成分对于维持稳定性的效果并不总是非常理想，第二子成分（负反馈）是纠正性的反

subsystem.

Passive Component

The passive component consists of the vertebrae, intervertebral discs, zygapophyseal joints, and ligaments of the spine (O'Sullivan et al., 1997). As mentioned earlier, the passive structures of the spine alone are highly unstable, with the thoracolumbar spine buckling under 20 N (Lucas and Bresler, 1961) and the isolated lumbar spine buckling under 88 N (Crisco, et al., 1992). Panjabi (1992) agreed, as he stated the passive component provides the least amount of stability of the three components. In fact, in the neutral position the passive component does not provide significant stability, it is only at the end-ranges of motion where the ligaments become stretched and limit spinal movement. Furthermore, these same ligaments can be classified under the neural control component, which will be discussed later, due to the fact they provide information on vertebral position and movements (Panjabi, 1992). In agreement with Panjabi, Willson et al. (2005) claimed the contribution of the passive component was small, and was the product of the interaction of a load placed on the bony architecture and the compliance of the soft tissue. Although some claimed the role of the passive structures were small in comparison to the other components, the intervertebral discs play a significant role in the stability of the spine since the discs aid in movement and transmit forces along the vertebrae (Walsh and Lotz, 2004). In addition, it has been noted that injury to the intervertebral discs can occur and cause the spine to be less stable. Saal (1992) stated repetitive movements and torsional stress to the lumbar intervertebral discs and facet joints could lead to degeneration, which might develop into spinal joint failure since the intervertebral discs were responsible for load transmission within the intervertebral segments.

The passive component of the core includes ligaments, vertebrae, intervertebral discs and joints of the spine. The primary role of this component is to limit spinal motion at the end-ranges and transmit forces between the vertebrae. Although, the role of the passive component is small, injury to the passive structures can cause joint failure and instability.

Active Component

The active component consists of muscles surround the core (Panjabi, 1992). Hodges (2004) stated the active system contributes to core stability by the force generating capacity of the muscles. Both Panjabi and Hodges suggested that although the active system was of significant importance to spinal stability it could not act alone and therefore must be included in the neural control component.

Willson, et al. (2005) included a detailed description of the role of the active component in their description of core stability. They introduced three mechanisms in which the active component contributed to core stability: intra-abdominal pressure, spinal compressive forces, and hip and trunk muscle stiffness. The first

应，受到外周神经受体的激活。神经控制成分综合利用正反馈（预期）和负反馈（反应）机制，以保持和恢复核心稳定。将一个动作区分为单纯的正反馈或负反馈是非常困难的，因为有时候两者共同起作用。

霍奇斯于2004年提出，核心稳定性的正反馈控制是在运动之前或在躯干施加负荷之前的提前准备措施。Riemann和Laphart于2002年提出，这种预先准备是由较高级的神经与大脑中枢所激活的，包括：大脑皮层，小脑或/和基底神经节。Riemann和Laphart于2002年提出大脑皮层运动区负责激发和控制复杂的自主运动；小脑负责协调运动的规划和调整；而基底神经节被认为参与高级的运动控制行为。

解释正反馈控制机制的最好例子是在上下肢运动之前和一个有预期的外在负荷施加到躯干上时，关于躯干肌肉如何被激活的研究，Friedli等人于1984年观察到不管躯干是否起到支撑或无支撑作用，也不论下肢是否施加了外负荷，在肘关节出现自主性运动之前，躯干（腹直肌，竖脊肌）和腿部肌肉（股四头肌，股二头肌）都出现了被激活的现象。同时也有学者观察到在下肢自主性活动之前也出现了躯干肌肉被激活的现象。Hodges等人于1997年观察到腹横肌、腹直肌、腹内斜肌和腹外斜肌在自主屈髋、外展和旋转之前被激活。其中腹横肌在3种髋关节活动中均最先被激活。另外有研究显示，在有下背痛（Hodges and Richardson，1998）和腹股沟疼痛（Cowan et al.，2004）的个体的预期机制中，腹横肌出现了激活延迟现象。当一个人事先知道会有负荷施加在躯干部位时，中枢神经系统可以激活躯干肌肉以应对负荷。Moseley等人于2003年观测到，在受试者所拿着的桶中逐渐增加一定的重量，并且提前告知受试者，在7名受试者中，有6人的深层腰多裂肌被激活。为了保持核心稳定性，神经控制成分需要为预知的负荷和运动做好主动准备的能力。

Ebenbichler等人于2001年提出，神经控制成分的负反馈机制提供了有关核心和其它关节所处位置和运动的本体感觉信息。与稳定性相同，本体感觉在科学文献中有不同的含义。因此，在本文中使用Riemann和Lephart于2002年提出的定义：本体感觉主要描述机体内外的传入信息，与姿势控制、稳定性和有意识的感觉有关。提供本体感觉信息的感觉组织被称作机械性感受器，存在于肌肉、肌腱、韧带和关节囊中。4种常见的机械性感受器有鲁菲尼受体、帕齐尼受体、肌梭和高尔基腱体。鲁菲尼受体和帕齐尼受体都位于韧带及关节囊中。鲁菲尼受体被认为是牵张感受器，而帕齐尼受体是压力感受器（Hogervorst和Brand，1998年）。肌梭位于肌纤维内，提供有关肌肉的长度和长度变化的信息（Riemann和Lephart，2002年）。高尔基腱体位于肌肉肌腱连接处，提供肌肉的张力信息（Riemann和Lephart，2002年）。关节或者姿态重新定位测试常被用来检测本体感觉。Gill和Callaghan于1998年研究了个体在有无腰痛的情况下，在站立和四肢接触地面情况下重新姿势定位的情况。研究结果显示，不论是站立或者四肢接触地面的情况，没有腰痛的个体重新定位更精确。因为，疼痛有可能会损害本体感觉信息的输入，而本体感觉信息输入是核心稳定的神经控制成分的一个重要方面。

为了更好地解释核心稳定性的负反馈控制，我们研究了事先没有预期的负荷或者干扰作用于核心部位时肌肉的激活

mechanism, intra-abdominal pressure, which is the amount of pressure within the abdominal cavity, is achieved by activation of the abdominal muscles, namely the transversus abdominis (Hodges, 2004), the diaphragm, the pelvic floor muscles (Willson et al., 2005), and tension of the thoracolumbar fascia (Tesh, et al., 1987). Intra-abdominal pressure functions in spinal stability by creating a pressured filled cavity anterior to the spine causing a force against the apex of the lordosis of the lumbar vertebrae, limiting the segmental movement when performing activities (Hodges, and Richardson, 1996). Furthermore, increases in intra-abdominal pressure may decrease the compressive loads on the spine and may reduce the risk for injury (Daggfeldt and Thorstensson, 2003). Gardner-Morse and Stokes (1998) illustrated the second mechanism of stability, as they conclude that antagonistic co-activation of the abdominal muscles will increase spinal stability by increasing the compressive forces placed on the spine. They estimated antagonistic co-activation of the trunk flexor and extensor muscle increased compressive loading by a maximum of 21% during a 40% effort task with the external obliques providing the greatest gains. The last mechanism in which the active component contributes to core stability, according to Willson et al. (2005), is to produce stiffness in the hip and trunk muscles. They stated that unless the trunk was loaded, the muscles in the hips and trunk were virtually inactive and the passive structures would be required to be the main stabilizers of the core.

The active component of the core plays a vital role in core stability, but different muscles assist in different ways. The muscles of the trunk can be divided into two muscle systems: local and global muscles (Bergmark, 1989). Bergmark described the local muscles as deep muscles that have their origin or insertion at the vertebrae. Their roles are to control the curvature of the spine and provide sagittal and lateral stiffness. The major local muscles included the transverse abdominis, the lumbar multifidus, and the posterior fibers of the interal obliques (O'Sullivan, et al., 1997). These muscles, specifically the lumbar multifidi, have large percentages of type I fibers (58-69%) and larger type I fiber size, which help their supportive capabilities (Richardson, 1999). The global muscles were large, superficial muscles which do not attach directly to the vertebrae (Bergmark, 1989). These muscles generate movement in the trunk, balance external loads, and transfer loads from the thorax to the pelvis (Hodges, 2004). These muscles included the erector spinae muscles, the internal (all but the posterior fibers) and external obliques, the rectus abdominal muscles, and the lateral segments of the quadratus lumborum. Although the local and global muscles are located and function differently, it is of vital importance that they work together in order create and uphold stability of the spine (Hodges, 2004).

Neural Control Component

The final component involved in core stability is the neural control component. Panjabi (1992) suggested for spinal stabilization to occur the neural control component must receive information from

情况。据Mosslely等人于2003年进行的研究与观察，发现事先预期到的负荷和没有预期的负荷施加到人体时，肌肉激活的情况是不同的，最主要的区别是人体的肌肉没有产生预先激活现象（Cresswell等人，1994年）。当一个事先没有预期的负荷或者干扰施加在机体上时，一个应激反应机制立刻被启动，以保持稳定性。这种应激性的反应可能体现出不同的神经反射水平，根据外界干扰的程度、类型和方向，有的是单突触牵张反射（Hodges，2004），有的采用更加复杂的自主姿势性反射（Ebenbichler等人，2001年）。人体受到小的干扰只需要通过激活踝关节周围的肌肉，即所谓的“踝关节策略”来应对干扰，恢复平衡。当应对大的干扰的时候，人体则会采用“髋部策略”，通过特定的髋部动作来应对干扰，从而保持身体的正常姿态，重新获得稳定性。

总而言之，核心稳定性的神经控制成分综合运用了正反馈和负反馈控制，激活并保持核心稳定性和平衡性。人体受到负面因素的影响，如疼痛，会破坏到正反馈和负反馈系统，甚至造成稳定性的缺失。

4 小结

通过人体解剖学结构，明确“核心”在人体的位置；明确核心稳定性中的稳定性的内涵；解释核心稳定性的功能性构成成分。“核心”的位置包括连接人体上肢和下肢的全部骨骼、肌肉和神经组织。稳定性的定义根据研究的机体系统和运动形式的不同而有所不同。当研究人体核心稳定性的时候，可能没有精确的定义。但是，描述核心稳定性的重点是在没有伤病的情况下，在静态和动态动作中能够保持整个身体以及胸部-腰骨盆部的平衡性的能力。核心稳定性分为3个相互关联的的子系统：被动的肌肉骨骼系统，主动的肌肉骨骼系统和神经控制系统。核心稳定性的被动成分包括椎体、韧带、椎间盘、肋骨、骨盆，臀部和肩部的骨骼，其主要作用是提供结构和限制活动范围。虽然，被动成分在维持核心稳定性的作用较小，但是，被动结构损伤可能会导致关节功能丧失；核心稳定性的主动成分通过3个途径来发挥作用：腹内压、脊柱间压力，髋部和躯干肌肉弹性强度。根据主动成分在人体上的位置和功能的不同，可以分为全局或局部肌肉系统。两组系统必须通过共同努力来获得核心的稳定性。最后，为了保持稳定性，神经控制成分必须接收来自机体内外传递的信息，按照稳定性的特定要求，激活主动成分产生收缩。此外，神经控制成分综合运用正，负反馈机制来保持核心的稳定。

a number of transducers, to determine specific requirements for stability, and then to initiate contraction of the active component. Hodges (2004) stated the central nervous system (CNS) continually interpreted information sent by afferent nerves from the peripheral mechanoreceptors, compared this information to what was considered “appropriate stability or posture”, and stimulates muscle activity in a precise manner to maintain control of the spine. Although Panjabi and Hodges’s statements are well accepted in the literature, they described simply one of the mechanisms which contribute to the neural control component. Aruin and Latash (1995) proposed there were two subcomponents of the neural control component. The first subcomponent (feed-forward) is the anticipatory adjustment of the core to movement or perturbations (Aruin and Latash, 1995). Since first subcomponent’s efficacy is suboptimal, a second subcomponent (feed-back) is required. The feed-back subcomponent is a corrective response, which is initiated by the peripheral receptors (Aruin and Latash, 1995). The neural control component acts collectively using both feed-forward (anticipatory) and feed-back (reaction) mechanisms, to retain and restore stability (Aruin and Latash, 1995). Classifying an action as solely feed-forward or feed-back control is difficult, since at times a combination of the two would be used (Riemann and Laphart, 2002).

The feed-forward control of core stability results from advanced preparation before a movement occurs or before a load is placed on the trunk (Hodges, 2004). This advanced preparation is initiated at the higher levels of motor control: cerebral cortex, cerebellum, and / or basal ganglia (Riemann and Laphart, 2002). The motor cortex allows for the initiating and managing of complex voluntary movements (Riemann and Laphart, 2002). The cerebellum is responsible for the planning and adjustment of coordinated movement, while the basal ganglia are thought to be involved in high-order aspects of motor control (Riemann and Laphart, 2002).

The feed-forward control mechanism can best be demonstrated by studies which show the activation of trunk muscles occurring before movement of both the upper and lower extremities and when an expected load is placed on the trunk. Friedli et al. (1984) observed activation in trunk (rectus abdominis, erector spinae) and leg muscles (quadriceps, biceps femoris) before voluntary movement at the elbow occurred in conditions where the trunk was supported and not supported and with or without a load placed on the upper extremity. Activation of trunk muscles before voluntary movement of the lower extremity has also been observed. Hodges et al. (1997) witnessed activity of the transverses abdominis, the rectus abdominis, internal obliques, and external obliques muscles before voluntary hip flexion, abduction, and extension. The transverses abdominis muscles preceded all other muscles for all three hip movements (Hodges et al., 1997).

Other studies have shown delayed activity of the transverses abdominis muscles as a repertory mechanism in individuals with pain in the low back (Hodges and Richardson, 1998) and groin (Cowan et al., 2004). When an expected load is placed on the trunk, the CNS can activate the trunk muscle in anticipation of the load. Moseley et al. (2003) observed activation of the deep lumbar mulifidus muscles in six of the seven participants as an expected weight was dropped into a bucket they were holding. In order to maintain stability in the core, the neural control component must have the ability to prepare the active component for movement and for an expected load.

The feed-back mechanism of the neural component provides proprioceptive information on the whereabouts and movements of the core and other joints (Ebenbichler et al., 2001). Same as for stability, proprioception is a term with several different meanings in the scientific literature. Therefore, we use Riemann and Lephart's (2002) definition which states proprioception describes afferent information from internal peripheral areas that contribute to postural control, stability, and conscious sensations. The sensory structures which provide proprioceptive information are called mechanoreceptors and are located in the muscles, tendons, ligaments, and joint capsules. Four common mechanoreceptors are the Ruffini receptors, Pacini receptors, muscle spindles, and the Golgi tendon organs. The Ruffini receptors and Pacini receptors are both located in ligaments and joint capsules. The Ruffini receptors are thought to be stretch receptors, while the Pacini receptors are activated by compression (Hogervorst and Brand, 1998). The muscle spindles are located in muscle fibers and provide information relating to muscle length and change in muscle length (Riemann and Lephart, 2002). The Golgi tendon organs are located in the musculotendinous junction and provide information muscle tension (Riemann and Lephart, 2002). To test proprioception, a joint or postural repositioning test are commonly used. Gill and Callaghan (1998) studied the ability of individuals with and without low back pain to reproduce a postural position in both standing and four-point kneeing. The study observed individuals without low back pain were more accurate in repositioning in both the standing and four point kneeing positions. Therefore, pain may impair the proprioceptive input, which is an important aspect of the neural component of core stability.

To best demonstrate feed-back control of core stability, we examine the actions that occur when an unexpected load or perturbation impacts the core. It has been observed that muscle activation differs in situations when an unexpected load is placed on the body compared to an expected load (Moslely et al., 2003), with the major difference being a lack of the pre-activation of postural muscles (Cresswell, et al., 1994). When an unexpected load or perturbation is placed on the body, a response mechanism is activated to restore stability (Ebenbichler, et al., 2001). This reaction can be initiate at the reflex level using the monosynaptic stretch reflex (Hodges, 2004) or using more complex automatic postural responses which are equal to the magnitude, type, and direction of the perturbation (Ebenbichler et al., 2001). Small perturbations can initiate the "ankle strategy" where muscles around the ankle are recruited to restore equilibrium, while larger perturbations require the "hip strategy"which imposes specific hip movements to reestablish an upright posture (Ebenbichler et al., 2001).

In summary, the neural control component of core stability uses both feed-forward and feed-back control, to initiate and maintain core stability and equilibrium. Impairments, such as pain, can cause disruption to both the feed-forward and feed-back systems, which may lead to loss of stability.

Conclusion

The objectives of this paper are to identify the core's location on the body using anatomical structures, define stability as it relates to the core stability, and explain the functional components that make up stability. The location of the core can include any neural and muscular-skeletal structure which connects the upper and lower extremities. Stability may be defined in several different ways, and may require a different definition depending of the system or movement being studied. When studying core stability a pinpoint definition may not be available, but the main focus of a description should include the ability to control both whole body and thoracolumbopelvic equilibrium in both static and dynamic activities without injury. There are three interdependent subsystems which create the core stabilizing system: the passive musculoskeletal, the active musculoskeletal, and the neural control subsystems. The passive component include ligaments, vertebrae, intervertebral discs, ribs, pelvis, and bones of the hips and shoulders. Their primary role is to provide structure and limit motion at the end-ranges. Although, the role of the passive component is small, injury to the passive structures can cause joint failure. The active component contributes to core stability in three ways: intra-abdominal pressure, spinal compressive forces, and hip and trunk muscle stiffness. The muscles of the active component can be classified as either local or global muscles depending on their location and their function. Both groups must work together in order to achieve a stable core. Finally, in order to maintain stability the neural control component must receive information, determines specific requirements for stability, and then initiate contraction of the active component. In addition, the neural control component uses both feed-forward and feedback mechanisms collectively, to maintain stability.

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期以往就会出现局部肌肉的疲劳积累，造成慢性损伤，甚至会产生运动中的急性撕裂和断裂。而在悬吊这样的不稳定环境下训练，能从本质上暴露出动力链中某些薄弱环节，将有助于运动员和教练员发现问题，并且通过针对性的训练来消除这些薄弱点，以及可能引起的损伤风险。悬吊训练就是一种预防运动性损伤和提高核心稳定性的方法。

4 小结

无论是水疗、普拉提训练还是悬吊训练都是运动员非常好的体能康复训练方法，也是运动能力的辅助训练方法。水疗与水中训练主要应用于康复领域，尤其运动员伤病后的恢复。普拉提训练和悬吊训练经济适用，更加适合竞技运动员用于加强核心稳定性，进行肌力、柔韧性、爆发力和协调性的整合。合理地选择和正确地应用体能康复训练不仅能够预防运动性伤病和伤病的康复，而且能够提高运动员的运动能力。因此，在康复和竞技领域有着非常广阔的应用前景。

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