The Jargon of Pedal Movements

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The Jargon of Pedal Movements

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ABSTRACT

Background: **All areas of research have their own specialized terms. Typically jargon is used as a short cut among specialists to convey complex ideas with a few brief words or phrases. Several jargons traditionally have been used to describe movements of the foot and ankle. It has been long recognized that these terms have no uniform meanings, which leads to confusion when attempting to synthesize reports from different researchers. Although many researchers are aware of this problem, few seem to be aware of how pervasive it is within the published literature. This report focuses on the depth of variation in uses of the terms inversion and eversion and pronation and supination in describing foot motions.** ***Methods:*** **A survey was sent out via the Internet to three communities: biomechanists, clinical anatomists, and podiatrists. A similar survey was conducted of published articles that appeared during a 10-year period in 16 scientific journals. These surveys provide data on the use and interdependencies of how pronation and supination and inversion and eversion are defined.** ***Results:*** **There are at least 18 different working definitions of inversion and eversion and 20 working definitions of pronation and supination. Several of the definitions were shown to be mutually contradictory.** ***Conclusions:*** **Specialists have failed to describe foot movements in a way that can be unambiguously interpreted. Mutual incomprehensibility of foot movements complicates the interpretive value of any report of foot movements. It is suggested that a new set of terms may help prevent this type of confusion in the future.** ***Clinical Relevance:*** **The lack of unambiguous descriptions in the research literature may mean that clinicians are not always applying treatment options in an appropriate manner. Greater clarity of meaning is required for both basic research and clinical applications.**

Key Words: Eversion; Inversion; Pronation; Supination

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INTRODUCTION

"When I use a word," Humpty Dumpty said in rather a scornful tone. "It means just what I choose it to mean - neither more or less."
"The question is," said Alice, "whether you can make words mean so many different things."
"The question is," said Humpty Dumpty, "which is to be master - that's all."

Lewis Carroll
Through the Looking Glass

The language of science strives to provide clear, unambiguous descriptions of methods, observations, and interpretations. It is perhaps not surprising to state that the communications of all scientific disciplines frequently fall short of this noble objective.[2] One source of this failing is the use of specialized technical terms, called jargons. The use of jargons can grow to be so powerful that as researchers become more specialized they soon fail to recognize their word choices as jargons. This becomes the bane of cross-disciplinary researchers who experience greater difficulties deciphering reports as they move farther from their home discipline. Human biology is perhaps the most cross-disciplinary of scientific endeavors, and useful synergies frequently are stifled by the use of mutually incomprehensible jargons. Although I have not attempted to make the necessary cross comparisons, I would hope that no area of human biology makes use of more conflicting and confusing jargons than are found within the descriptions of pedal movements.

There is a well documented confusion in the use of the descriptive jargons of pedal movement. One edition of Gray's Anatomy makes note of this problem by stating that the "terminology of pedal movements is somewhat confused amongst orthopaedists, kinesiologists and others" (p. 538).[17] This confusion has been exacerbated in recent years with the implementation of computer models that strive to describe joint movements as positive or negative rotations in a way that is consistent throughout the body. Achieving

this consistency has compelled some researchers to either redefine or abandon the traditional terms of movement. To this end, there are several jargons of pedal movement that merit closer investigation. However, no set of terms seems to be more confusing, and confused, than the couplets: inversion/eversion and pronation/supination.

The history of the terms inversion, eversion, pronation and supination as applied to the foot and ankle was definitively reported by McDonald and Tavener;[7] their findings are briefly summarized here. It seems that these terms have independent origins and did not originate as closely linked pairs. Early anatomists (18th century and earlier) struggled to describe foot movements and had to fall back on descriptions like twist, turn, bend, or move inward and outward. The word "eversion" first appeared in a text by J. Quain[11] in 1828 and was used to describe the action of fibularis (peroneus) longus. While the original use of "inversion" is not identified, the inversion/eversion couplet had gained fairly universal acceptance as descriptive terms of foot movement by the mid 1800's. Early uses of the pronation/supination couplet appeared in comparative anatomy studies to describe movements of the fibula relative to the tibia and were thus applied in a way that is more directly analogous with the upper limb. Studies in the 1920's by Morton[10] and Weidenreich[16] on comparative primate anatomy and evolution are credited with the first uses of pronation/supination to describe intrinsic foot motions, probably because of the hand-like resemblance of the nonhuman primate foot. Morton[10] extended this practice to a clinical discussion of foot disorder and, thereby, introduced foot pronation/supination to the clinical lexicon.

Most anatomists, biomechanists, and clinicians who deal with the foot and ankle have a firm grasp of the associated complicated movements or at least they fulfill the Socratic dictum of wisdom in that they know what they do and do not understand. Many also are aware that pronation/supination and inversion/eversion are used differently by different authors. However, researchers and clinicians, or more notably journal editors and manuscript reviewers, do not seem to be aware of the implications of this diversity. In some cases, an author can use these terms in a way that is directly contradictory to the way a reader understands them. In so doing, research clarity is muddled, conclusions are misunderstood, and scientific progress is undermined.

This report presents data on the depth, diversity, and interrelationships of the jargons inversion and eversion and pronation and supination as applied to the foot and ankle. The discussion will highlight apparent contradictions and circular definitions that may not be evident to the casual investigator. A potential solution is offered in the form of a new set of descriptive perspectives and terms.

MATERIALS AND METHODS

The initial phase of this investigation was based on a survey sent out to the biomechanics, clinical anatomy, and podiatry Internet communities. A letter of inquiry was sent to each of these listservers that outlined the problem and requested personal responses from the community membership. This request was sent out twice, with the second posting being accompanied by a summary of the results obtained from the first posting. Each community also was provided with a final summary of these survey results.

The internet survey responses did not always conform to the requested format. Responses were in the form of definitions written in sentences. Since it was rare that two people would provide identical definitions, some level of subjective grouping was necessary. No response was rejected unless the respondent indicated that they were quoting from a book or some other authority. This decision was made because the goal of the survey was to determine how members of these disciplines read and think about these terms. It would have been inappropriate for this purpose to allow respondents to quote from some text that may not be universally consulted. Undoubtedly there were a few instances of respondents quoting from texts that were not recognized as such. With these caveats in place, all replies were considered to be equally valid examples of how knowledgeable and informed people treat these terms. Because of these subjective decisions, some researchers would undoubtedly create different groupings and therefore obtain slightly different summary statistics from these same data. These are unavoidable methodological problems associated with internet or reader response surveys. Despite these problems, the internet survey provides a unique opportunity to assess open-ended responses. Participants were able to express opinions on how terms were interrelated, whether they could or should be considered as synonyms, and whether the terms were inappropriate and should not be used. These open-ended responses provided a framework for the categorization of definitions obtained from the more rigorous survey of journal articles.

The second phase of this research focused on the published use of the words pronation, supination, inversion and eversion in the academic literature. Published articles that spanned a 10-year period (1994 to 2003) in 16 journals were perused. The journals were selected based on their presumed association with the anatomy, biomechanics, and clinical care of the foot and ankle. The selection of journals also represented a sample of convenience, limited by their availability within the library of my home institution. This survey identified 296 relevant articles (the list can be obtained from the author upon request). No further mention will be made of any particular article, or its authors, with respect to its use as a source of data for this survey. The intent here is to avoid any perception of ridicule or embarrassment to any particular individual. The peer-review process should ensure that each article reflects its discipline's state-of-the-art in the use of pedal jargons. It is the state-of-the-art that is being investigated, not the individual practitioners. The survey of journal articles examined definitions that were included within each

manuscript. In many cases, no definitions were provided, which became a new category in the classification of each jargon.

RESULTS

The internet survey was sent out to over 5000 potential respondents and garnered 72 responses that could be included in this analysis. Several respondents supplied multiple definitions, usually associated with the differences of motion that would occur in an open versus closed kinematic chain. Table 1 presents the 18 different definitions that were obtained for inversion and eversion. Each of these definitions is given a letter designation: A through R. Although the differences among some of the reported definitions are subtle, no single definition reflects the majority opinion. Indeed, the majority opinion (61%) would find that the most common definition (A) was either incomplete or entirely incorrect.

Table 2 presents the 20 different definitions that were obtained for pronation and supination from the survey. Each of these definitions is given a numerical designation: 1 through 20. Again, some of the differences among the reported definitions are subtle, but there is an even greater diversity of opinion of how pronation and supination should be defined. The majority of researchers (71%) would claim that the most common definition of pronation and supination (1) was either incomplete or entirely incorrect.

A subset of the respondents (n = 54) provided definitions for both sets of terms. Table 3 reports the frequency of interactions between these definitions. In this subset, pronation/supination Definition 1 is favored by 36%. However, only 22% of the respondents agreed on the meaning of pronation/supination based on their agreed definition of inversion/eversion (Definition 1A). It is also noteworthy that while inversion/eversion was included as part of the definition of pronation/supination, 2% of the respondents who cited this definition also claimed that inversion/eversion are inappropriate terms that have no place in scientific discourse (Definition 1R).

The survey of journal articles essentially repeats and confirms the findings of the internet survey. Of the 296 articles examined, 163 made use of the terms pronation/supination, 225 used the terms inversion/eversion, and 94 articles used both terms. Table 4 reports the treatment of the terms inversion/eversion in these articles. The overwhelming majority (67%) fail to define these terms. Of the articles that do provide definitions, there is again no clear majority opinion. Definition A is still the most popular choice, and Definition E is an apparent second. Again, a large majority of the published researchers would disagree with any single choice.

Table 5 reports the usage of the terms pronation/supination among the published articles. Once again, 67% of the authors choose not to include a definition of these terms within their manuscript. When definitions were provided, Definition 1 was most popular (28%) followed closely by Definition 6 (25%). Interaction effects (Table 6) show that 20% of the authors fail to define inversion/eversion while they do define pronation/supination. A similar proportion (17%) fail to define pronation/supination while they do define inversion/eversion. Definition 1A is still the modal definition where both definitions were provided. However, the majority of authors (53%) rely on the "self evident" meanings of these terms and provide no definitions at all.

DISCUSSION

The results of the journal article survey complements but does not override the internet survey. The internet survey contains a bias in favor of those who were willing to respond. Therefore, its results do not necessarily reflect the opinions of all who contribute to the discipline. Similarly, the journal article survey contains an unavoidable bias in favor of the opinions of those who publish more frequently either as first or as supporting authors. There may also be an unidentifiable editorial bias that would compel some authors to use terms in a way that they would not normally consider to be appropriate, or to avoid the issue by not providing definitions. Therefore, the journal survey provides a broader sampling of how these jargons are being used, but the internet survey provides a more in depth investigation of each person's understanding of the jargons. Because of these biases the reported frequencies of usage associated with each definition may not perfectly reflect frequencies of opinions that exist within the community of human biology scholars. However, where the two surveys agree, the diversity of definitions in use and the lack of majority support for any one definition should be accepted as a valid indicator of a problem within scholarly discourse.

Seemingly subtle differences exist among some of the definitions that were categorized in the survey results. Some readers may wish to combine two or more definitions, and in some cases this combination may be supportable. However, because of the presented diversity of definitions, it may not be correct to assume that "a medial motion about the long axis of the foot" is always, and to all people, the same thing as "an inward movement of the foot in the coronal plane." These subtle differences also may mask a more complicated situation. For example, inversion/eversion Definitions A, B, C, E, G, F, H and O all describe a medial/lateral, or inward/outward, tilt of the foot. Yet some of these definitions are limited to movements of the forefoot (G and H) while others are limited to movements of the hindfoot (E and F). When specifying a movement of the forefoot, it may not be correct to assume that the hindfoot is moving in concert. If independent movement is assumed, and the orientation of the forefoot is defined by its relationship to the hindfoot, then a medial tilt of the forefoot could be accomplished by a lateral tilt of the hindfoot. Thus, some of

Table 1: Inversion/eversion definitions from the internet survey

Percentage of responses	Designation	Definition
39%	**A**	Motion about the long axis of the foot so that the sole faces medially/laterally
4%	**B**	Inward/outward rotation of the foot occurring at the subtalar and talocrural joints
3%	**C**	Movement at the talocrural joint in which the sole of the foot is rotated in the frontal plane to face medially/laterally
3%	**D**	Open kinematic chain movement associated with ankle plantarflexion/dorsiflexion, rearfoot adduction/abduction and a varus/valgus movement of the foot.
8%	**E**	Motion about the subtalar joint so that the sole of the hindfoot faces medially/laterally
3%	**F**	Hindfoot motion in which the heel moves laterally/medially, leading to a valgus/varus heel.
8%	**G**	Medial/lateral movement of the forefoot in the plane of the sole
3%	**H**	Forefoot moves toward/away from the midline of the body in the frontal plane
4%	**I**	Combination of supination/pronation, adduction/abduction and plantarflexion/dorsiflexion
3%	**J**	Combination of adduction/abduction about the subtalar joint and supination/pronation about the transverse tarsal joint
3%	**K**	Combination of supination/pronation, adduction/abduction and dorsiflexion/plantarflexion
3%	**L**	Supination/pronation about the subtalar and transverse tarsal joints and plantarflexion/dorsiflexion at the talocrural joint
2%	**M**	Synonym with subtalar supination/pronation
3%	**N**	Combined movements of internal/external rotation (supination/pronation, adduction/abduction and plantarflexion/dorsiflexion)
3%	**O**	Internal/external rotation of the hindfoot, supination/pronation and adduction/abduction of the forefoot
3%	**P**	Close kinematic chain movement associated with external/internal rotation of the foot (combination of tibial movement and foot supination/pronation)
2%	**Q**	Synonym with foot adduction/abduction
4%	**R**	No such thing, inappropriate term

Where descriptive terms are separated by a slash (term1/term2) the first of the pair refers to inversion, while the second refers to eversion. Percentage values add up to more than 100% because of rounding errors and because several respondents provided more than one definition.

Table 2: Pronation/supination definitions from the internet survey

Percentage of Responses	Designation	Definition
29%	**1**	Motion about the subtalar joint involving forefoot eversion/inversion, dorsiflexion/plantarflexion and abduction/adduction
4%	**2**	Movement of the foot that combines eversion/inversion, dorsiflexion/plantarflexion and external/internal rotation
3%	**3**	Combination of tibial medial/lateral rotation, ankle dorsiflexion/plantarflexion, calcaneal abduction/adduction and eversion/inversion
3%	**4**	Open kinematic chain movement produced by calcaneal eversion/inversion, forefoot abduction/adduction and dorsiflexion/plantarflexion
4%	**5**	Closed kinematic chain movement produced by calcaneal eversion/inversion, talar adduction/abduction and plantarflexion/dorsiflexion
10%	**6**	Motion about the long axis of the foot so the sole faces laterally/medially
3%	**7**	Movement about the calcaneocuboid joint so that the sole of the foot faces more laterally/medially
3%	**8**	Movement about the subtalar and transverse tarsal joint so that the sole faces laterally/medially
4%	**9**	A forefoot movement that lowers/raises the hallux while raising/lowering the 5th digit
3%	**10**	Components of eversion/inversion that takes place mainly at the subtalar joint to create a valgus/varus heel
3%	**11**	Combination of movements that reduces/increases the height of the medial longitudinal arch
3%	**12**	Decrease/increase of the medial longitudinal arch that occurs via subtalar eversion/inversion, midtarsal extension/flexion and internal/external rotation of the tibia
3%	**13**	Same relative motions as eversion/inversion, but under weight bearing conditions
3%	**14**	External/internal rotation at the transverse tarsal joint combined with abduction/adduction and dorsiflexion/plantarflexion of the ankle joint. Synonymous with eversion/inversion
3%	**15**	Open kinematic chain movement of the foot associated with adduction/abduction, extension/flexion and internal/external rotation. Similar to eversion/inversion, but does not require movement of the talus and tibia.
3%	**16**	Internal/external rotation about the subtalar joint
3%	**17**	Plantarflexion/dorsiflexion of the talar head, adduction/abduction of the talar head and inversion/eversion of the calcaneus
3%	**18**	Movement at the posterior facet of the subtalar joint such that the talus slides anteriorly/posteriorly and inferiorly/superiorly
4%	**19**	A closed kinematic chain motion associated with ankle dorsiflexion/plantarflexion, rearfoot abduction/adduction and a plantar/dorsal movement of the foot into a loose packed position. Associated with midstance/heel strike during gait
9%	**20**	No such thing, inappropriate term

Where descriptive terms are separated by a slash (term1/term2) the first of the pair refers to pronation, while the second refers to supination. Percentage values add up to more than 100% because of rounding errors, and because several respondents provided more than one definition.

Table 3: Interdependencies of the inversion/eversion and pronation/supination definitions, based upon data from the internet survey

		Inversion/Eversion																	Totals
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	
Pronation/Supination	**1**	22	2	2		6	2											2	**36**
	2							2	2										**4**
	3	2																	**2**
	4																	2	**2**
	5	2																2	**4**
	6					4		4		2									**10**
	7										2								**2**
	8											2							**2**
	9	2													2				**4**
	10	2									2								**4**
	11	2																	**2**
	12	2																	**2**
	13	2																	**2**
	14													2					**2**
	15															2			**2**
	16	2																	**2**
	17	2																	**2**
	18												2						**2**
	19	2			2														**4**
	20	11	2														2		**15**
Totals		**53**	**4**	**2**	**2**	**10**	**2**	**6**	**2**	**2**	**4**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	

Definition designations follow the patterns of the previous tables. Numbers represent the percentage out of 54 interdependencies derived from the survey. Percentage totals do not sum to 100% because of rounding and because of multiple definitions provided by some respondents.

these definitions are directly contradictory to each other. This contradictory perspective seems even more problematic when some definitions require a tilt of the whole foot (A, B, and C) in the same direction, while Definition O specifically states that the forefoot and hindfoot are moving independently.

There is further confusion of the perceived relationships between inversion/eversion and pronation/supination. Seven definitions of pronation/supination (Definitions 1, 2, 3, 4, 13, 17 and 21) include inversion/eversion as a component movement; about 45% of the respondent's definitions rely on this relationship. Similarly seven definitions of inversion/eversion (Definitions B, I, J, K, N, O and P) include pronation/supination as a component movement, which was associated with about 23% of the respondent's definitions. Although these statistics imply a circularity of definitions, true circularity (e.g., eversion requires pronation and pronation requires eversion) occurs only in Definition 1B, which was proposed by only 2% of the respondents. None of the other definitions incorporate circular references. The implication is that each of the researchers who used these definitions has a clear and consistent concept of the movements that were being described. The real question is whether researchers are communicating those concepts to each other with equal clarity.

Another opportunity of a seeming circularity arises with Definition 6 for pronation/supination because it is identical to Definition A for inversion/eversion. This identity of definitions is not an accident of my subjective categorization but reflects nearly direct quotes derived from both the internet and journal article surveys. It is also important to note that there is no instance of a researcher proposing the 6A definition couplet in either the internet or the journal surveys. Although these identical definitions may seem circular, the researchers who use them are thinking about distinctly different movements. In both the internet and journal surveys, Definition 6 was the second most popular definition, although in the journal survey it was almost as popular as Definition 1 (25% vs. 28%). One might infer from these results that these researchers would consider pronation/supination to be a synonym for inversion/eversion, but that conclusion would not be supported by the data. It is unlikely that an author would list synonyms of their chosen jargon in print, and no instance of this was found in the journal survey. In the internet survey, 2%

Table 4: Inversion/eversion definitions from the journal survey

Percentage of Responses	Designation	Definition
67%		Terms used, but not defined.
45%	**A**	Motion about the long axis of the foot so that the sole faces medially/laterally
9%	**B**	Inward/outward rotation of the foot occurring at the subtalar and talocrural joints
1%	**C**	Movement at the talocrural joint in which the sole of the foot is rotated in the frontal plane to face medially/laterally
1%	**D**	Open kinematic chain movement associated with ankle plantarflexion/dorsiflexion, rearfoot adduction/abduction and a varus/valgus movement of the foot.
21%	**E**	Motion about the subtalar joint so that the sole of the hindfoot faces medially/laterally
5%	**F**	Hindfoot motion in which the heel moves laterally/medially, leading to a valgus/varus heel.
7%	**G**	Medial/lateral movement of the forefoot in the plane of the sole
1%	**H**	Forefoot moves toward/away from the midline of the body in the frontal plane
4%	**I**	Combination of supination/pronation, adduction/abduction and plantarflexion/dorsiflexion
3%	**K**	Combination of supination/pronation, adduction/abduction and dorsiflexion/plantarflexion
4%	**R**	No such thing, inappropriate term
1%	**S**	Inward/outward bend of the (superior-inferior) calcaneal line relative to the leg line

Where descriptive terms are separated by a slash (term1/term2) the first of the pair refers to inversion, while the second refers to eversion. Since 67% of the surveyed articles do not report a definition for inversion/eversion, the reported percentages for each definition reflect the proportion from the pool of articles where definitions were provided. Percentage values add up to more than 100% because of rounding errors. Definition designations are the same as those found in table 1 with the addition of Definition S, which did not appear in the Internet survey.

of the respondents did claim that inversion/eversion was a synonym for pronation/supination (Definition M). However, Table 3 shows that these researchers chose Definition 18 for pronation/supination. Similarly, the internet survey identified Definition 14 where pronation/supination was claimed to be synonymous with inversion/eversion. Definition 14 was coupled with Definition N, which includes pronation/supination as a component of inversion/eversion. Careful reading of Definition 14N suggests that pronation/supination might be similar to internal/external rotation.

The problem of circular definitions really only arises when two researchers (acting as author and reader) employ mutually circular definitions without realizing it. The survey results indicate that while most researchers may have a clear idea of what they mean by eversion/inversion and pronation/supination, researchers run the risk of conveying no useful information when they use those terms in communications with their colleagues. In some cases, a researcher will actually convey information that is exactly opposite to what was meant. This diversity of opinions transcends mere semantics. Beyond the confusion that these definitions create among basic researchers, the more telling consequence is upon clinical applications. **Every clinician who reaches for an orthotic device or applies a clinical procedure to treat a patient with "over pronation" must ask himself "does pronation mean the same thing to me as it did for the person who developed this treatment?"** In some applications, this confusion may cause the most well meaning clinician to apply the most inappropriate treatment. This confusion may in part explain why an off-the-shelf foot orthotic, or rehabilitation protocol, may work wonders for some patients and work not at all for others.

It would be incorrect to assert that the terms of movement as applied to the upper limb have any claim of priority or precision over their applications to the lower limb. Still, their application to the upper limb seems to be less ambiguous and therefore less problematic. Wrist flexion can be seen as directly comparable to ankle plantarflexion, while wrist

Table 5: Pronation/supination definitions from the journal survey

Percentage of responses	Designation	Definition
67%		Terms used, but not defined
28%	**1**	Motion about the subtalar joint involving forefoot eversion/inversion, dorsiflexion/plantarflexion and abduction/adduction
4%	**2**	Movement of the foot that combines eversion/inversion, dorsiflexion/plantarflexion and external/internal rotation
4%	**4**	Open kinematic chain movement produced by calcaneal eversion/inversion, forefoot abduction/adduction and dorsiflexion/plantarflexion
4%	**5**	Closed kinematic chain movement produced by calcaneal eversion/inversion, talar adduction/abduction and plantarflexion/dorsiflexion
25%	**6**	Motion about the long axis of the foot so the sole faces laterally/medially
4%	**8**	Movement about the subtalar and transverse tarsal joint so that the sole faces laterally/medially
4%	**9**	A forefoot movement that lowers/raises the hallux while raising/lowering the fifth digit
2%	**10**	Components of eversion/inversion that takes place mainly at the subtalar joint to create a valgus/varus heel
9%	**11**	Combination of movements that reduces/increases the height of the medial longitudinal arch
2%	**12**	Decrease/increase of the medial longitudinal arch that occurs via subtalar eversion/inversion, midtarsal extension/flexion and internal/external rotation of the tibia
2%	**13**	Same relative motions as eversion/inversion, but under weight bearing conditions
12%	**16**	Internal/external rotation about the subtalar joint
2%	**17**	Plantarflexion/dorsiflexion of the talar head, adduction/abduction of the talar head and inversion/eversion of the calcaneus
2%	**20**	No such thing, inappropriate term
2%	**21**	Combination of eversion/inversion and dorsiflexion/plantarflexion

Where descriptive terms are separated by a slash (term1/term2) the first of the pair refers to pronation, while the second refers to supination. Since 67% of the surveyed articles do not report a definition for pronation/supination, the reported percentages for each definition reflect the proportion from the pool of articles where definitions were provided. Percentage values add up to more than 100% because of rounding errors. Definition designations are the same as those found in table 2 with the addition of Definition 21, which did not appear in the Internet survey.

extension pairs with dorsiflexion. Pronation/supination in the upper limb describes a movement that occurs roughly about the long axis of the forearm and is accomplished by the movement of the radius on the ulna at the radioulnar joints; it also is associated with the rotation of the radial head on the capitulum of the humerus. In the lower limb, the accommodative movements of the fibula relative to the tibia would be the closest analog to upper limb pronation/supination. The next closest analogous movement is the rotation of the tibia on the femoral condyles about the long axis of the leg. In the lower limb this action produces the same relative motion as upper limb pronation/supination. But this lower limb action also has a confused jargon. The rotation of the tibia on the femoral condyles is typically designated medial/lateral (or inward/outward) rotation of the knee. Yet, with reference to the foot and ankle this same motion is frequently termed adduction/abduction.

In the upper limb, adduction at the wrist is accomplished at the radiocarpal joint by an ulnar deviation of the hand, while abduction is a radial deviation. In accordance with developmental serial homology, adduction at the ankle would be associated with a fibular deviation of the foot at the talocrural joint, while abduction would be associated with a tibial deviation. Some researchers use adduction/abduction in this way. However, because of the opposite directions of limb rotation during development, the lower limb is

Table 6: Interdependencies of the inversion/eversion and pronation/supination definitions, based upon data from the journal survey

		Inversion/Eversion									Totals
		Used, but not defined	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**I**	
Pronation/Supination	**Used, but not defined**	53	6	2		1	2			1	**65**
	1	9	6		1				1		**17**
	2	1									**1**
	4	1									**1**
	5	1									**1**
	6	3					1				**4**
	9							1			**1**
	10	1									**1**
	11	3									**3**
	12	1									**1**
	16						1				**1**
	17		1								**1**
	20		1								**1**
	Totals	**73**	**14**	**2**	**1**	**1**	**4**	**1**	**1**	**1**	

Definition designations follow the patterns of the previous tables. Numbers represent the percentage out of the 94 articles identified in the survey that made use of both terms. Percentage totals do not sum to 100 because of rounding errors.

oriented 180 degrees from the upper limb in anatomical position. This leads some researchers who are unaware of, or unimpressed by, developmental issues to define ankle adduction as a tibial deviation of the foot and abduction as a fibular deviation. All three definitions (rotation of the tibia on the femur and the two directions of tilt of the foot on the leg) can be justified from an anatomical, kinesiological, or biomechanical perspective. Yet, these definitions also are mutually exclusive. It was made clear during the journal surveys that all three definitions of ankle adduction/abduction are being used. It was not clear which of these definitions is most popular, or if still more definitions are in play.

Inversion/eversion would seem to be the most straightforward of the movement terms that are being discussed here. Several anatomy texts[2,9,12,17] state that inversion is the foot movement produced by the actions of the tibialis anterior and tibialis posterior muscles, while eversion is accomplished by the actions of fibularis longus, fibularis brevis, and fibularis tertius (peroneals). That definition may be completely defensible from an anatomical perspective, but it is also completely useless to the needs of kinesiologists, biomechanists, and clinicians. Because of the permanently dorsiflexed position of the foot, inversion/eversion has no named analog in the upper limb. If the wrist is held in extension to simulate a foot-like position, a twisting action of the hand can be accomplished by alternately activating the wrist adductors (flexor carpi ulnaris and extensor carpi ulnaris) and abductors (flexor carpi radialis, extensor carpi radialis brevis and extensor carpi radialis longus). Similarly, a foot held in extreme plantarflexion to simulate the hand-like position achieves a tibial deviation through the actions of the "inverter" muscles and a fibular deviation through the actions of the "everter" muscles. From these associations, it would appear that there is a serial homology between the muscular inversion/eversion actions of the ankle and foot and the adduction/abduction actions of the wrist and hand. In the internet survey, 2% of the respondents claimed that inversion/eversion is a synonym of foot adduction/abduction (Definition Q). However, this definition still does not resolve the direction of foot and ankle adduction/abduction. Does definition Q assert that foot inversion is a synonym of foot adduction or abduction?

Several definitions seem to avoid this problem by describing varus and valgus movements. To some this may seem a reasonable solution; however, it is not clear if varus/valgus movements are being used in a way that avoids the adduction/abduction problems. To others, varus and valgus only refers to the shape or deformation of a bone. There will be some instances where bone deformation is exactly what is occurring.[4] Therefore, it can be important to retain jargons that distinguish movements that occur at a joint from movements that occur from bone deformation.

One of the original goals of the internet survey was to identify an association among definition choice and academic background and training. This was not attempted with the journal survey, because academic training and departmental affiliation are not necessarily well correlated. In any case, there was no obvious association. This result supports the

findings reported by McDonald and Tavener.[7] There is no apparent rhyme or reason as to why researchers use the definitions that they use. This increases the complexity of the problem, because it also means that a solution will not be easily achieved.

Undoubtedly some readers of this article would still want to dismiss the differences that have been highlighted among some definitions. Those readers should focus on the not so subtle differences that also exist. Not even the most creative mind could reconcile inversion/eversion Definitions E and G, or pronation/supination Definitions 1 and 20. Individuals can reasonably differ on whether the reported results should be grouped into twenty definitions or into three. The problem still remains that there is more than one accepted definition for each set of terms. More than one definition means that there has been a failure in scientific communication. That is a problem that needs to be addressed.

A Proposed Solution

Researchers, as a community of individuals, appear to be wedded to their own sets of terms, so much so that many are offended when it is suggested that their use of these terms is different from the mainstream, or that their definitions are different from that of their academic group. Many researchers will likely be shocked to learn that their academic group does not employ a uniform set of definitions.

The problem of nebulous definitions has not gone unrecognized, and there have been many attempts to impose solutions. In the Orthopaedic Foot and Ankle Society Ad Hoc Committee Report, January 1996, the Standard Terminology and Measurement Subcommittee[13] recommended Definitions 1 and A. By virtue of their authority, one might assume that there would be a trend toward the adoption of these standards after publication. There has been no such trend. Allowing for a 1-year lag before these recommendations could take effect, even the journal that published this report contained articles (in the period 1998–2003) that make use of six different definitions of pronation/supination and seven different definitions of inversion/eversion. The International Society for Biomechanics produced a very similar set of guidelines,[18] with a similar lack of compliance within its membership. Further examples of professional organizations attempting to solve this issue can be cited, along with a similar lack of conformity among the professions.

It should be apparent that standardized definitions of inversion/eversion and pronation/supination cannot be successfully imposed on the scientific community. The crux of the problem lies with the familiarity of the current set of jargons. Everyone "knows" what these terms mean. Just about everyone agrees that if there is someone employing a different definition, then it is that someone who must be in error. This is a Gordian knot that cannot be untangled and that instead must be cut.

Movements within the body generally are assumed to occur about axes that emerge from one of three mutually orthogonal planes: frontal, sagittal, and transverse. Movement that occurs around an axis that emerges from the sagittal plane is typically termed flexion/extension; about an axis out of the frontal plane yields abduction/adduction; and about an axis that emerges from the transverse plane produces medial/lateral (or inward/outward) rotation. The definitions of these standardized body planes and their associated movements do not apply well to the human foot (Figure 1). Because of the permanently dorsiflexed position of the human foot, some workers exchange the orientation of the frontal and transverse planes. This realignment of the planes is supportable from a developmental perspective, so that the planes maintain their functional definitions when applied to the foot. In this realignment, the transverse plane continues to separate proximal from distal segments while the frontal plane separates ventral from dorsal segments. The problem with this new orientation is that it creates difficulties in associating foot movements with movements in the rest of the body. Note how pronation/supination Definitions 1 and 2 differ only in their use of rotation compared to abduction/adduction. Perhaps those definitions are identical and it is the reference planes that are different. For the purposes of standardization, it is suggested that the anatomical planes not be realigned to meet the special circumstances found in the foot. Using standard anatomical alignment means that the transverse plane divides the foot into ventral (plantar) and dorsal segments, while the frontal plane divides the foot into proximal and distal segments.

Although few joint axes conform perfectly to the anatomical standards, their orientations usually are close enough that the conventional terms of movement can be unambiguously applied. This type of conformity frequently does not apply to movements within the foot and ankle. When a joint axis is aligned 20 degrees to one of the reference body planes, conventional terms of movement can be used without too much ambiguity. For example, the primary axis of motion at the talocrural joint frequently is described as being about 8 degrees from the transverse plane and 20 degrees from the frontal plane.[6,8] These values are close enough to the conventional expectations of flexion/extension to be described by those terms (the specialized terms of plantarflexion/dorsiflexion are preferred only because of the permanently extended position of the human foot, the usage of the terms are synonymous with flexion/extension). However, when a joint axis is aligned halfway between two of the reference body planes it becomes difficult to describe that motion. For example, the primary axis of the subtalar joint has been described as being about 42 degrees from the transverse plane and 23 degrees from the sagittal plane.[6] Movements about this axis are poorly described by any of the conventional terms. Some specialists refer to this motion as a "triplanar" action, as if it can be parsed into three distinct movements associated with the reference body planes (this interpretation could be inferred from Definitions 1—5). Other specialists use those triplanar definitions but

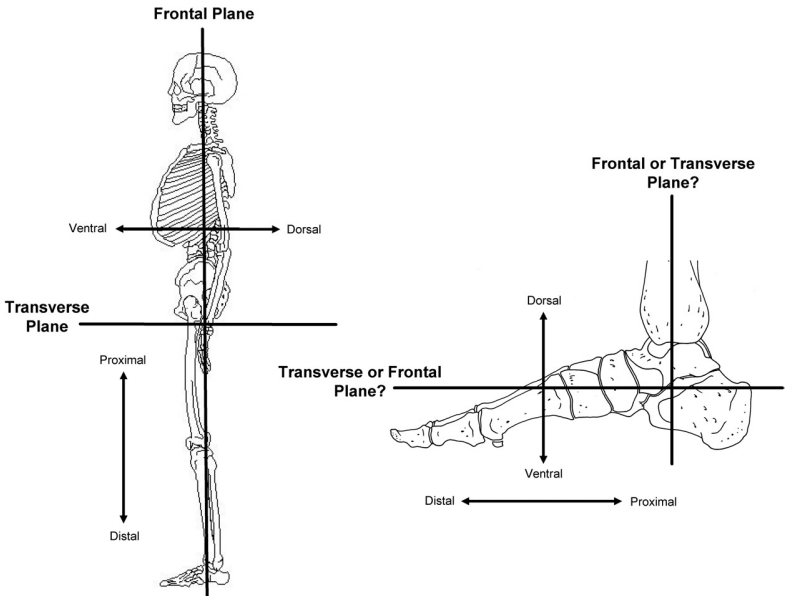

Fig. 1: In the standardized anatomical posture, the frontal plane divides the body into ventral and dorsal segments while the transverse plane divides the limbs into proximal and distal segments (image on the left). The permanently dorsiflexed position of the human foot could be seen to transpose the transverse and frontal planes relative to their positions for the rest of the body (image on the right). Researchers are left with a decision. They can maintain the definitions of these planes so that in the foot these planes are shifted 90 degrees from their applications in the rest of the body. Or, the original criteria of the body planes can be retained, which will exchange their applied meanings within the foot. The confused use of rotation and abduction/adduction may stem from the ambiguity of how these body planes should be applied to the foot. **For the purposes of standardization, it is suggested that the planes as applied to the entire body be preferred over their re-orientation for foot specific applications. Thus, the transverse plane divides the foot into dorsal and ventral segments, while the frontal plane separates the foot's proximal and distal elements**.

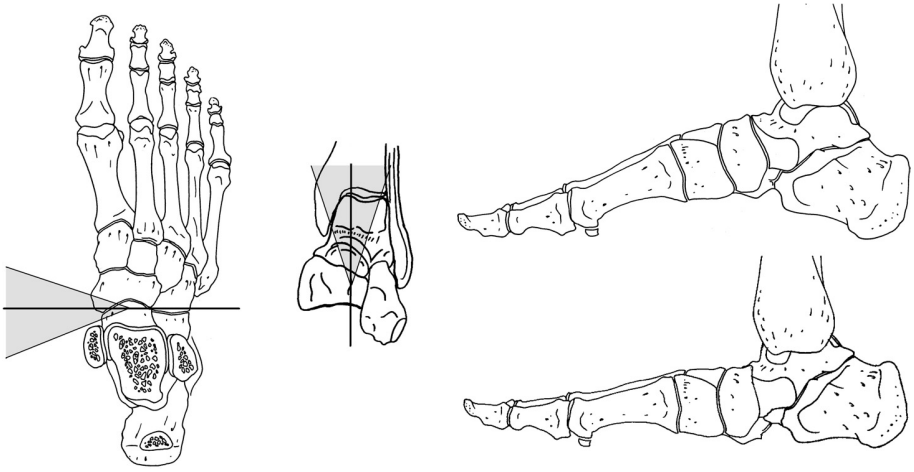

Fig. 2: An example of dorsiflexion of the navicular on the talus at the talonavicular joint. The left hand images show the ranges of variation for the orientation of the axis of plantarflexion or dorsiflexion around the idealized value. The axis emerges from the sagittal plane and lies roughly parallel to the transverse plane (left most image) and the frontal plane (central image). The two right hand images show the navicular dorsiflexed (lower right image) relative to its starting position (upper right image). The net effect of dorsiflexion at the talonavicular joint is to flatten the longitudinal arch of the foot. In this extreme example other intrinsic joint motions would also be necessary to result in the complete flattening of the foot's longitudinal arches that is shown here.

illustrate their definitions with axes that are still aligned with the orthogonal reference planes. A new set of terms would be useful to describe the movements that occur about nonorthogonal axes. Although each of the intrinsic joints of the foot and ankle is associated with its own unique motion, this discussion will focus on naming movements about three of the more critical joints: talocrural, subtalar, and talonavicular. In all the following illustrations, uniform application requires that each term is used to describe the distal element moving on a "fixed" proximal element, without regard to how those motions might actually be created in the human body.

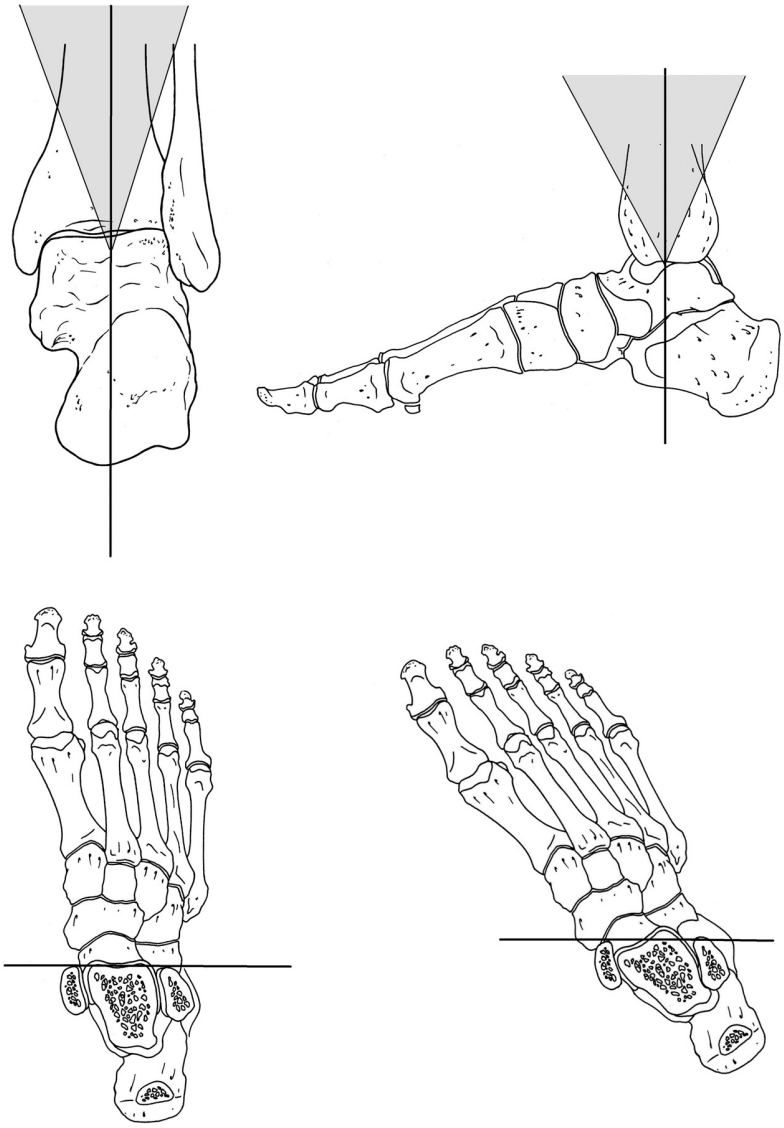

Fig. 3: An example of a medial (or inward) rotation of the talus at the talocrural joint. The upper images show the ranges of variation around the idealized value for the orientation of the axis of rotation. The axis emerges from the transverse plane and lies roughly parallel to both the sagittal (upper left image) and the frontal (upper right image) planes. The two lower images show the talus, and foot, medially rotated (lower right) relative to its starting position (lower left). This definition of rotation for the ankle would allow the movement to conform to the term's usage when describing rotations in most of the other joints of the body. It also provides a necessary distinction from the potential abduction/adduction movements of this joint described in Figure 4.

Plantarflexion/Dorsiflexion (Flexion/Extension)

These terms are relatively unique in that their current application in the literature appears to be fairly consistent and unambiguous when applied to the talocrural joint. Plantarflexion/dorsiflexion is equivalent to, and interchangeable with, flexion/extension. The terms refer to movements about an axis that emerges from the sagittal plane and lies roughly parallel to both the transverse and frontal planes. Plantarflexion (flexion) folds a developmentally ventral surface upon another ventral surface, while dorsiflexion (extension) folds a dorsal surface onto another dorsal surface. Although individual variation may be associated with an axis that is oblique to the reference planes, average movements across individuals should result in an axis that is reasonably close to an orthogonal orientation. Movements about axes defined in this fashion are common, as for the interphalangeal and metatarsophalangeal joints, or possible, as in the talonavicular joint (Figure 2). Dorsiflexion at the talonavicular joint may, in some cases, be the movement that is responsible for the observation of a "navicular drop."

Medial/Lateral (Inward/Outward) Rotation

For most joints of the body, rotation is used to describe a motion about an axis that emerges from the transverse plane and that lies roughly parallel to the sagittal and

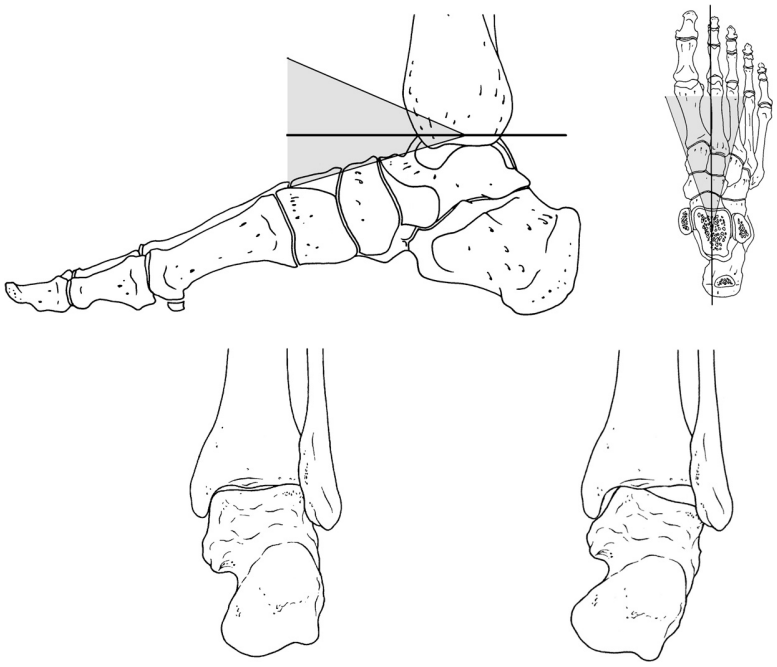

Fig. 4: An example of an adduction of the talus at the talocrural joint. The upper images show the ranges of variation around the idealized value for the orientation of the axis of abduction/adduction. The axis emerges from the frontal plane to lie roughly parallel to both the transverse (upper left image) and sagittal (upper right image) planes. The two lower images show the talus adducted (lower right) relative to its starting position (lower left). This is an extreme example of adduction that would probably not normally occur, although a small degree of nonpathological abduction/adduction is possible especially in the fully plantarflexed position. This definition of abduction/adduction for the ankle would allow this movement's definition to conform to the term's usage when describing movements in most of the other joints of the body. It also provides a necessary distinction from the potential rotational movements of this joint that are described in Figure 3.

frontal planes. Medial (inward) rotation causes an anterior surface to turn more toward the midline of the body, while lateral (outward) rotation reorients this surface away from the midline. The application of this definition becomes confused with most of the foot joints because of the nonorthogonal orientation of the foot when in anatomical position. Still, this standardized definition will work well when used to describe movements of the talus within the talocrural joint (Figure 3). Again, because individual variation may be associated with an axis that is oblique to the reference planes, terminology should rely on average movements across individuals that would result in an axis that is reasonably close to the orthogonal orientation. Researchers should resist the tendency to describe a reorientation of the foot that is produced by knee or hip rotations as if it were a foot or ankle movement.

Abduction/Adduction

This movement typically is associated with an axis that emerges from the frontal plane and that lies roughly parallel to the transverse and sagittal planes. (A special case can apply when abduction/adduction is used to describe movements at the metatarsophalangeal joints in much the same way as they are applied to the metacarpophalangeal joints in the hand. Here, the axis emerges from the transverse plane and is associated with movements away from, or toward, the midline of the foot.) At the talocrural joint abduction/adduction can be used to describe movements in much the same way as it is used to describe movements at the radiocarpal joint (Figure 4). Abduction at the talocrural joint causes a fibular deviation of the foot, while adduction deviates the foot toward the tibial side. Foot abduction/adduction should not be used to describe a change in the foot's position relative to the body, but instead should be reserved for the movement at a specific joint, in this case the talocrural joint. Care should be taken in the distinction between abduction/adduction and rotation when the foot is held in extreme plantarflexion, and thereby alters the relationship of the foot to the standard anatomical planes. In all instances abduction/adduction is a movement that would potentially create a gap between the articular surfaces of the talus and the tibial plafond. Rotation is a movement that would maintain these surfaces in close congruity but would change the orientation of the talus relative to the medial and lateral malleoli.

Intorsion/Extorsion

These terms describe motions that are unique to the subtalar joint. Research[6,14] shows that the primary movement of the subtalar joint occurs about an axis that roughly runs from superior-anterior to inferior-posterior and from anterior-medial to posterior-lateral. As such, this axis emerges from

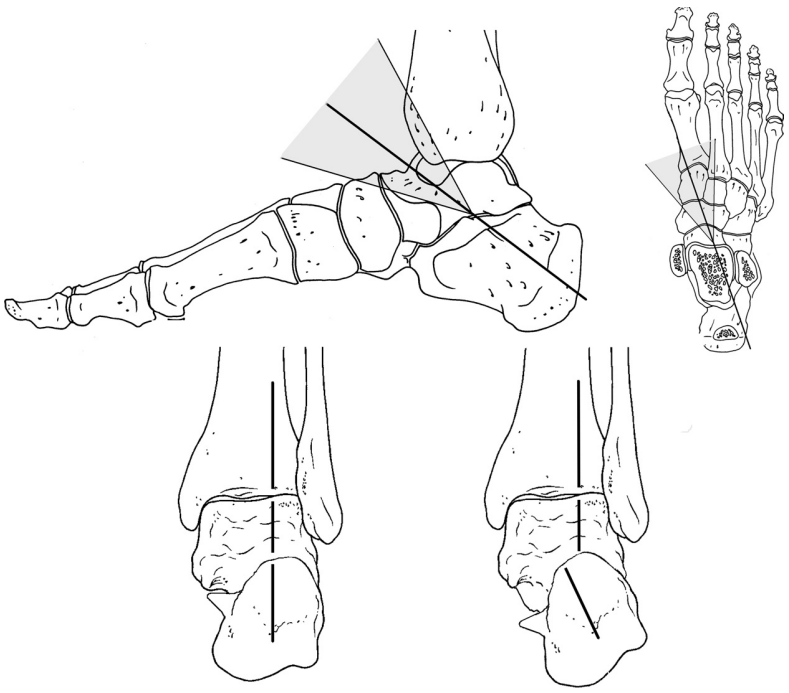

Fig. 5: An example of an extorsion of the calcaneous on the talus at the subtalar joint. The upper images show the ranges of variation around the idealized value for the orientation of the axis of intorsion/extorsion. The axis emerges from the frontal plane to lie between the sagittal and transverse planes (upper left image) and between the sagittal and frontal planes (upper right image). The two lower images show the calcaneus extorted (lower right) relative to its starting position (lower left). In this extreme example extorsion is illustrated by a folding so that the lateral surface of the calcaneus is inclined more toward the lateral surface of the talus. This same motion could also be described as a medially directed tilt of the superior surface of the calcaneus. The extreme amount of extorsion illustrated here would undoubtedly need to be accompanied by accommodative movements in the other intrinsic foot joints.

the frontal plane and lies oblique to both the sagittal and transverse planes. Because of its oblique axis, this movement cannot be adequately described by any of the conventional terms. Instead, intorsion/extorsion is proposed as a new jargon to describe this movement (Figure 5). An intorsion at the subtalar joint reorients the calcaneus so that its medial surface is angled upward and toward the medial surface of the talus. Extorsion reorients the calcaneus so that its lateral surface is angled upward and toward the lateral surface of the talus. For the purposes of uniformity, this description should always apply as if the talus were the fixed element, even though that may not always be the case.

Obversion/Reversion

These terms describe movements of the intertarsal joints. The axis of this movement emerges from the transverse plane and lies roughly parallel to the sagittal plane but oblique to the frontal plane. The oblique orientation of this axis may, for many joints, be roughly perpendicular to the plane of the metatarsals. As such, this axis may lie roughly parallel to the frontal plane in individuals with diminished longitudinal arches of the foot (as depicted in Figure 2) and could therefore produce a movement that is very similar to rotation as defined above. Reversion at the talonavicular joint (Figure 6) reorients the navicular so that its distal (anterior) surface angles away from the midline of the foot, which in this example would also shift the forefoot to point more towards the midline of the body. An obversion at the talonavicular joint shifts the distal surface of the navicular toward the midline of the foot. The definition of obversion/reversion makes reference to the midline of the foot in a similar fashion to metatarsophalangeal abduction/adduction (i.e., an imaginary line that divides the foot along the second digital ray).

Involution/Obvolution

This new jargon also describes movements of the intertarsal joints. The axis of this movement emerges from the frontal plane and lies roughly parallel to the sagittal plane and oblique to the transverse planes. In some instances this axis may seem similar to the description of the obversion/reversion axis, and so it must be stressed that these two axes are distinctly different, at least at the talonavicular joint.[5] Involution causes the inferior surface of the bone to incline more toward the midline of the foot. As such it causes a developmentally ventral surface to fold onto another ventral surface, but in a manner that is markedly different from flexion. Obvolution causes the inferior surface to incline away from the midline of the foot, and thereby approximates the folding of dorsal surfaces. The involution of the navicular at the talonavicular joint (Figure 7) would enhance the transverse arch of the foot. Involution of the talonavicular

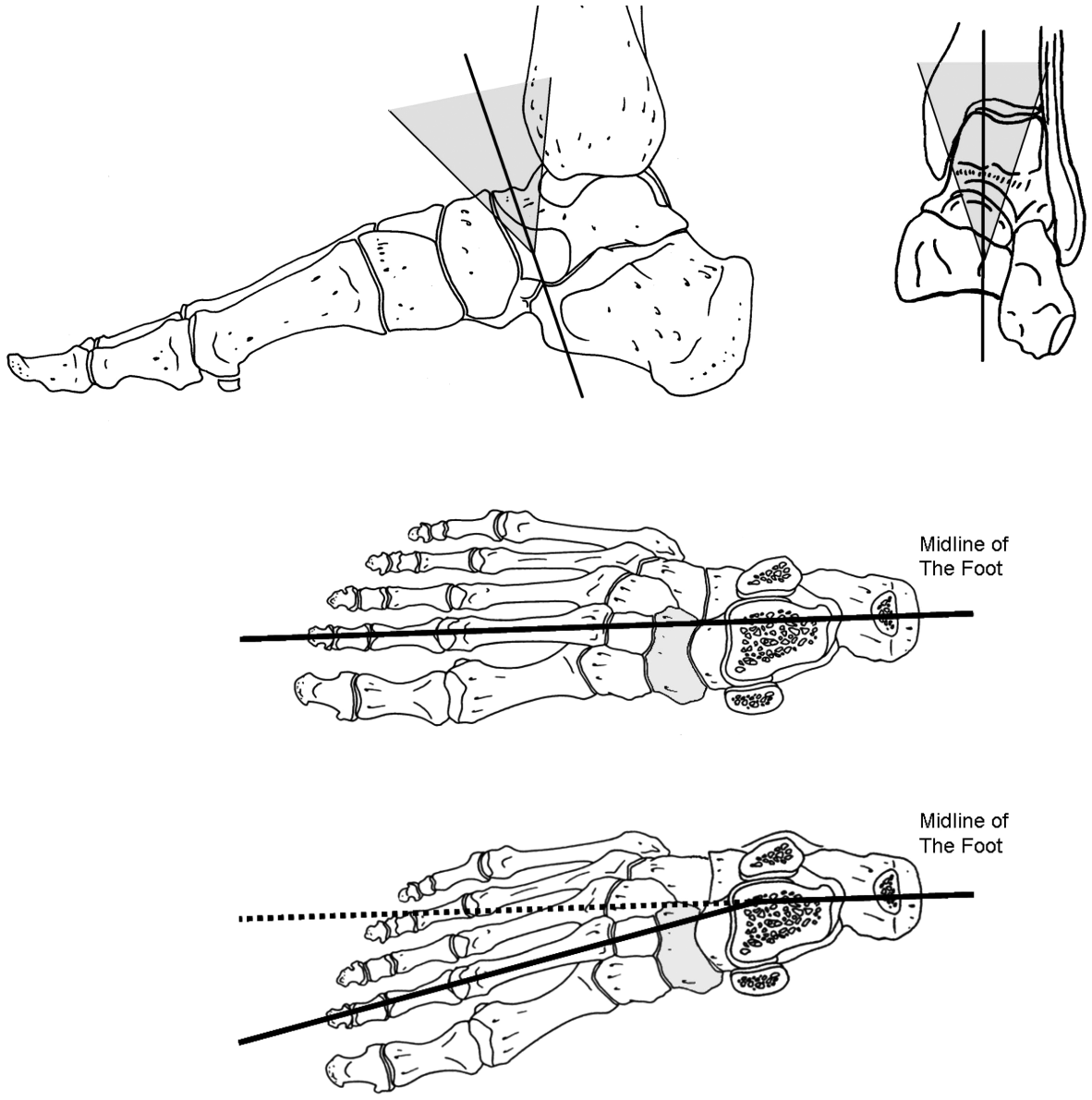

Fig. 6: An example of a reversion of the navicular on the talus at the talonavicular joint. The upper images show the ranges of variation around the idealized value for the orientation of the axis of obversion/reversion. The axis emerges from the transverse plane to lie roughly parallel to the sagittal plane (upper right image), but is located about midway between the frontal and transverse planes (upper left image). The two lower images show the navicular reverted (lowest image) relative to its starting position (middle image). The net effect of reversion at the talonavicular joint is to shift the distal face of the navicular away from the midline of the foot. In this extreme example, other intrinsic joint motions would also be necessary to result in the severe reorientation of the toes that is illustrated here.

joint is another movement that may be responsible for the observation of a "navicular drop."

These new jargons focus on descriptions of movements within the intrinsic joints and not on movements of the entire foot and ankle. The intent associated with the introduction of these new terms and refined definitions is to circumvent the preconceived notions associated with the current set of descriptive jargons. By providing a vocabulary of intrinsic joint movements, researchers can more precisely define the actions they are evaluating. Many of the movements described in these illustrations will have extremely low magnitude in the nonpathological condition. However, when descriptive terms are made available for even these small motions we will have reduced the ambiguity associated with intrinsic foot motions. Researchers who wish to investigate these motions can report upon them without having to struggle for the appropriate descriptive term. Meaningful discussions can then take place as to whether motion A is trivial while motion B is important. Similarly, researchers who insist on using the term "pronation" in the sense of

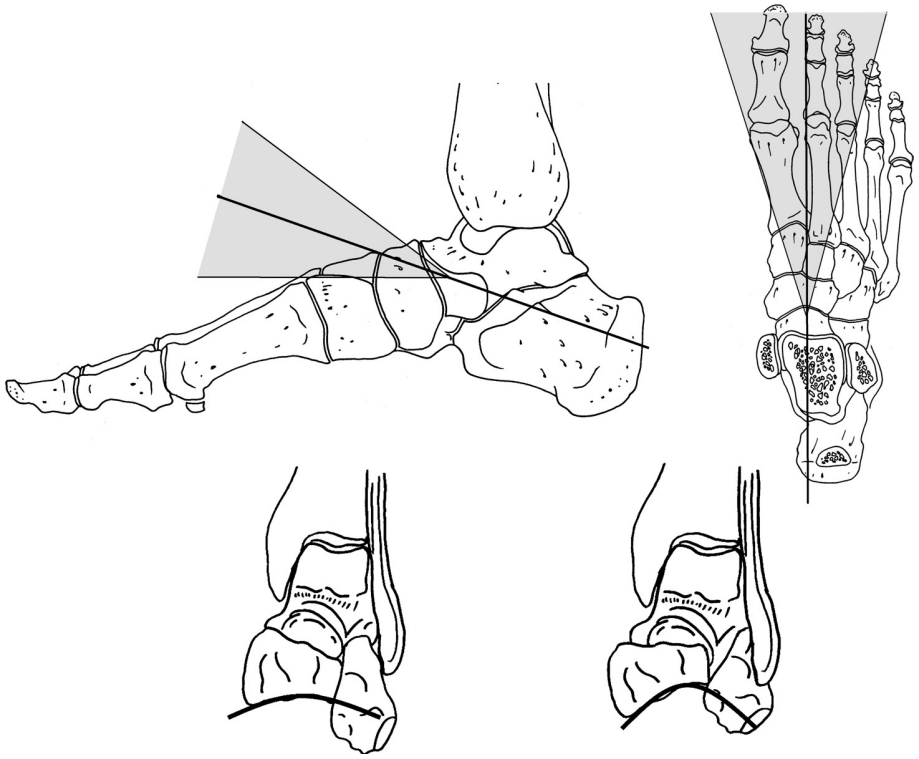

Fig. 7: An example of an involution of the navicular on the talus at the talonavicular joint. The upper images show the ranges of variation around the idealized value for the orientation of the axis of involution/obvolution. The axis emerges from the frontal plane to lie between the frontal and transverse planes (upper left image) and roughly parallel to the sagittal plane (upper right image). The two lower images show the navicular involuted (lower right) relative to its starting position (lower left). The effect of an involution at the talonavicular joint is to heighten the transverse arch of the foot as depicted by the superimposed curve.

Definition 1A might be expected to define this movement within their manuscript as: "a simultaneous dorsiflexion and medial rotation at the talocrural joint, extorsion at the subtalar joint, obvolution at the talonavicular joint, and involution at the calcaneocuboid joint." Other combinations of intrinsic joint movements may be appropriate for researchers who have different concepts of what pronation Definition 1A means. By incorporating this type of descriptive precision, it no longer becomes relevant whether researchers agree that any particular suite of movements is appropriate to the name pronation. This perspective would also require researchers to focus on where the movements are occurring within the foot, rather than on the gross patterns that can be observed externally. Discourse can now focus where it belongs, on whether the listed suite of movements were measured properly, whether they need to occur simultaneously, or whether the increased range of motion in one joint can compensate for the decreased range in another.

Having outlined the depth of this problem, it would be presumptuous to believe that any proposed solution will gain widespread acceptance. However, until a solution is reached, it is vital that everyone define the terms used within their communications, no matter how simplistic or "textbook" those definitions may seem. Authors must resist, with all their strength, the efforts of reviewers and editors who may insist upon the removal of those definitions because they are deemed "superfluous." Recent technological advances in data collection methods[1,15] have made the precise description of intrinsic foot joint movements both possible and desirable. It is now reliant upon the community of scholars to insist upon a similar level of precision in scholarly discourse.

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