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Gait Measurement Descriptions of Human Tracks

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Abstract

Search and rescue missions use a variety of tools to find missing persons, one of which can be visual tracking. Trackers detect, interpret and document information about human contact with the ground. Humans typically move on two feet at various speeds. Movement as an obligate biped leaves a series of footprints that alternates from one side to the other. This pattern of footfalls is rather simple, and the footfalls can be easily divided into descriptive dimensions.

This work summarized published measurements of bipedal gait ground contact points in 70 resources. Four resource types were surveyed including 33 biomechanical gait analysis studies, 28 tracking resources, six forensic texts, and three others. This work focused on three basic measurements common to finding and interpreting footprints: (1) step/stride length, (2) straddle, and (3) pitch. This research found two ways to measure pitch, three ways to measure straddle, and seven ways to measure step and/or stride lengths.

A set of recommended dimensions, presented with a diagram and a glossary, includes straddle as well as right and left measurements for pitch, step length, and stride length. One conclusion is that clear communication of the technique(s) used is more important than how to segment and measure a series of human footfalls. This paper also advocates for consistency in techniques and terminology. Whether practitioners apply tracking in search and rescue, law enforcement, military, or other applications, trackers should be consistent in the use of names or dimensions used throughout their own practice.

Keywords

Tracking, Signcutting, Human, Search and Rescue, Step, Stride, Straddle, Pitch

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Introduction

Tracking usually connotes detecting traces of the presence or movement of something (e.g., a package in the mail, locating a cell phone or distress beacon, the evolution of fossilized species). From a search and rescue (SAR) perspective, this paper focuses on tracking as “finding and interpreting tracks and sign” (Speiden, 2009, 2018), specifically those of missing person(s).

Humans are the only mammals for whom the primary locomotion is walking or running on two feet (Alexander, 2004). Research on human locomotion started over 100 years ago, resulting in a wide array of publications including works by criminologists on footprint evidence (for example, Abbott, 1964; Bodziak, 2000; Cassidy, 1980; Cunningham, 2011; Gross, 1922) and physiologists’ research on gait dynamics (Alexander, 2004; Archbold & Mullarney, 2018; Borelli, 1681; Bowker & Messenger, 1988; Bradford, 1897).

Visual tracking practitioners, including military servicemen, law enforcement officers, and SAR professionals, have written books about tracking humans for decades (for example, Brown, Jr., 1983; Carss, 2000; Cheney, 2013; Cunningham, 2011; Davies, 2014).

Visual trackers employ tracking via the discovery of footprints or other disturbances created by foot or footwear contact with the ground. SAR trackers seek, detect, interpret (age of tracks, direction of travel, behavior, etc.), document, and follow tracks that may have been made by missing persons. SAR and law enforcement trackers also use tracking to find and document signs of prior criminal activity.

The ability to describe observations remains imperative to any tracker’s skillset. One facet of that ability includes accurate and precise gait measurements. Observation and analyses of gait dimensions can be used to distinguish one person’s footprints from others’ prints (Cunningham, 2011). Gait dimensions can be used to ensure that trackers are following the same person through conditions where unique tread details or other identifying

features may not be detected. Changes in a person's gait measurements can provide information regarding fatigue, injury, or other factors affecting the quarry's movement (Speiden, 2018a).

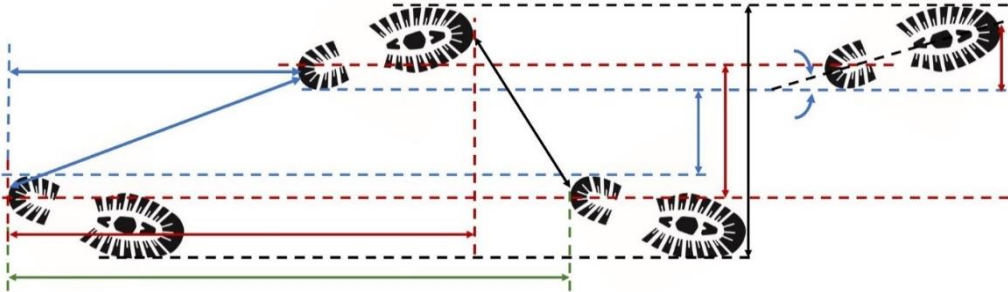


Figure 1. A diagram of human tracks showing the measurements discussed in this paper. **Which ones do you use or recognize, and what do you call them?**

Myriad trades that have published works related to interpreting human bipedal movement have also produced a variety of ways to describe gait measurements (See Figure 1). Different ways of describing the same dimension can lead to confusion. For example, several common names may be used for a plant that has one scientific name, or one common name may be used for more than one species of plant. Visual tracking techniques and terminology are no exception to that tendency.

This research describes the history and variety of gait measurement presentations related to tracking, with specific regard to measurements that could be applied to tracks left by a person moving on foot. In addition, this work presents an overview of different terminology and descriptions that may be encountered when looking at gait measurements in related literature. A set of gait measurement definitions convenient for trackers in the field are also recommended.

Method

This work is compiled of published works that offer a tracking-related description of gait measurements. All tracking and forensic resources found to contain gait measurement descriptions were included in the survey because this work describes gait measurements pertinent to visual tracking. Biomechanical analysis publications were also sought to describe the history and evolution of terms, methods, and descriptions. These resources were discovered from online research of human gait studies via keywords (step, stride, pitch, straddle), citations, and reference searches in Google Books, Google Scholar, ResearchGate, JSTOR, Heinonline, ScienceDirect, PubMed, and Semantic Scholar. After acquiring works from those platforms or databases, the references

within the discovered publications were also reviewed to find publications that weren't already included.

Descriptions or depictions of gait measurements that involved motion (e.g., swing time and stance time) were excluded from this research as they cannot be measured from tracks on the ground. Also excluded from this paper are works that only had written descriptions (as opposed to diagrams along with written descriptions). Except for a handful of historical references (Borelli, 1681; Braune & Fischer, 1895; Marey, 1895; Nussbaum, 1986; Weber & Weber, 1838) publications were only included if they were written in English as this paper explores semantic differences for the different terms.

Results

This review included a total of 70 resources. Four resource types were surveyed, including 33 biomechanical gait analysis studies, 28 tracking publications, six forensic texts, and three miscellaneous resources that did not fit into those first three categories. These different trades were explored to see if any differences occurred in any particular trade.

This review found two ways to measure foot angle, three ways to measure straddle and seven ways to measure step or stride length. Of the 70 resources, 29 (41%) of them mentioned dimensions for all three measurements. The other resources were included, even if they only described one or two of the three measurement types.

1 THE FIRST STEPS

The historical record of human gait study dates back to Aristotle who wrote *De Motu Animalium* in 344 BC (Nussbaum, 1986). Little additional work was found on the topic until Giovanni Borelli published a book, also titled *De Motu Animalium* in 1681. As noted by Mayer (2020) in *The Science of Walking*, “The efforts [in the late 1700s] to correct older tactics by describing military marching with greater mathematical precision mark the beginnings of experiment-based investigation into the mechanics of gait” (p.31).

The first dissection of the human gait was pioneered by French authors, the Weber brothers in 1838, and E. J. Marey in 1895. Subsequently, German anatomists Christian Braune and Otto Fischer published a series of papers on the biomechanics of human gait in 1895. None of these resources contained diagrams showing the measurements. As these studies were not written in English, and translation relies upon the interpreter, these publications were omitted from the summaries in this work. Suffice it to say that the only dimensions mentioned before the 1900s were those of two measurements: the distance between two subsequent footfalls (translated as “step” and “pace”) and the distance between a footfall and that same foot falling again (translated as “double step” and “double pace”) (Braune & Fischer, 1895; Marey, 1895).

The earliest records found of diagrammed ground contact point dimensions were in several resources published in the 1960s. Additional history can be found in more thorough summaries (*History of the Study of Locomotion*, n.d.; Mayer, 2020; Medved, 2000).

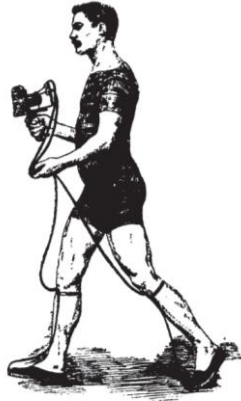


FIG. 4.—Pedestrian furnished with special shoes and carrying a chronographic apparatus.

Figure 2. A diagram of an early device used to measure the human gait. Reprinted from *Le Mouvement* by E.J. Marey, 1895, Editions J. Chambon p. 7.

2 STEP/STRIDE

This section discusses measurements of the length between footfalls along the direction of travel.

2.1 Heel to Heel of Consecutive Footfalls

There were 50 resources that described measuring the length between tracks from a point at one footfall to the same point at the subsequent footfall (e.g., right track to the next left track). These are most commonly shown as being measured from the back of one heel strike to the back of the next heel strike. Other ways depicted were front of heel to front of heel, and front of toe to front of toe, which would result in the same length as heel to heel. All those documents used either “step” or “stride” for that dimension.

Twenty-two publications, over half of which are tracking books, described a distance between consecutive footfalls to the exclusion of all other measurements. Five of those 22 publications referred to that distance as a “step” (Archbold & Mullarney, 2018; Contini et al., 1965; Grant, 2012; Gross, 1922; Wall et al., 2000). The remaining 17 publications called that distance a “stride”(for example, Brown, Jr., 1983; Cassidy, 1980; Cheney, 2013; Chodera & Levell, 1973; Diaz, 2005). One book that used “stride” also discussed different ways to measure it (Nellemann, 2011). None of these 22 works distinguished a similar measurement for either side of a person (right or left); whereas 25 other publications did, as discussed in the next few sections.

2.2 Heel to Heel of the Same Foot

Of the 50 resources that described the footfall-to-footfall distance, 25 also presented the length from a footfall on one side of the body to the next place that same foot contacted the ground again (e.g., the distance from one right track to the next right track). These sources all used the term “step” for the distance from one footfall to the next footfall (as described in section 2.1), and “stride” for the distance from one footfall to the next location that same foot contacted the ground.

These resources were predominantly biomechanical publications (for example, Alexander, 2004; Bowker & Messenger, 1988; Drillis, 1958; Frothingham, 2018), as well as five tracking books (Osuna, 2021; Speiden, 2009, 2018a, 2018b, 2023), and two forensic books by the same author (Bodziak, 2000, 2017).

2.3 Right and Left Sides

Inman (1981) writes: “The step dimension refers to the leg that is moved forward. Thus, the right step length is the distance from the back of the left heel (at contact) to the back of the right heel (at contact) ...” (p. 25). An example of that is shown in Figure 3. Just over half (13) of the 24 “step” and “stride” publications discussed and/or diagrammed a distinction between the right and left steps and strides.

Those 13 consisted of four tracking books (Speiden, 2009, 2018a, 2018b, 2023) and the remaining nine are gait analysis studies (for example, Uustal, n.d.; O’Sullivan et al., 1994, 2019; Richards et al., 2012; Whittle, 1991). One gait analysis resource (Levangie & Norkin, 2011), however, shows the right step length to be the distance from the back of the right heel (at contact) to the back of the left heel, which is the opposite orientation of feet for the name of the step or stride from the rest of the publications.

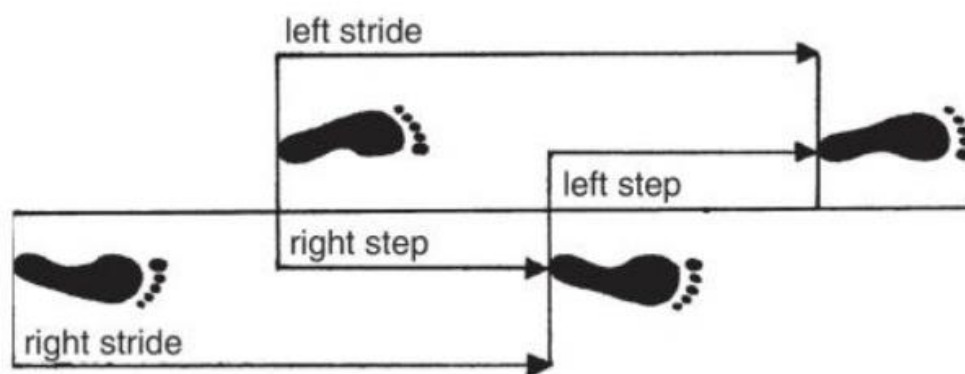


Figure 3. A diagram of both step and stride measurements for each side of the body. Reprinted from *Physical Rehabilitation Assessment and Treatment* (3rd ed.) (p. 168), by S. O’Sullivan, and T. Schmitz, 1994. Also included in subsequent editions, most recently 7th edition as Figure 7-2. Copyright 1994-2019 F.A. Davis Company. Reprinted with permission.

2.4 Same Foot Only

Seven tracking books (for example, Carss, 2009; Cunningham, 2011, 2016; Hardin, 2004; Kearney, 1999), one forensic book (Abbott, 1964), and two gait analysis articles (Drillis, 1958; Schwartz & Heath, 1947) omitted measurement references for the distance from any part of one foot to the subsequent footfall (e.g., right to left or left to right).

These ten resources either used a measurement of two consecutive footfalls from the same foot (e.g., right footfall to the next right footfall) which were called “step” (Schwartz & Heath, 1947), “stride” (Cunningham, 2011), “outside stride” (Cunningham, 2016), or a different means of expressing this dimension. None of these resources distinguished between a right and left measurement for these lengths.

2.5 Other Measurements

The different means of expressing this dimension were described in one of two ways. One description was as a measurement from the anterior (front) edge of the toe to the posterior (rear) edge of the next track of the opposite foot. This was called “step” (Cunningham, 2011), “stride” (Abbott, 1964), “inside stride” or “inner stride” (Cunningham, 2016), “step interval” (Kearney, 1978) or “stride interval” (Hardin, 2004).

One author diagrammed the second description for this measurement as the distance from the rear (posterior) edge of a heel to the front (anterior) edge of the toe of the next track. In all his books surveyed in this review, this distance was designated “total length of stride” (Carss, 2009, 2000, 2008). Similar to resources in section 2.2, one book included a heel to heel measurement of consecutive feet labelled “stride” (Kearney, 1978).

2.6 Step and Stride Summary

Figure 4 is a diagram summarizing all resources discussed in section 2 of this research. It compiles the myriad terms used to describe a length between ground contact points. The most commonly used terms were “step” length (in 30 (60%) of 50 publications) to be measured from a ground contact point of one foot to that point of the next footfall, and “stride” length (in 25 (50%) of 50 publications) measured from a ground contact point of one footfall to that same point at the next ground contact of the same foot. Those commonly used measurement techniques were selected and are recommended in the discussion and glossary sections. In the end, when comparing distances with others’ findings, the author recommends that trackers select one technique, remain consistent throughout the practice, and communicate how the measurement is accomplished.

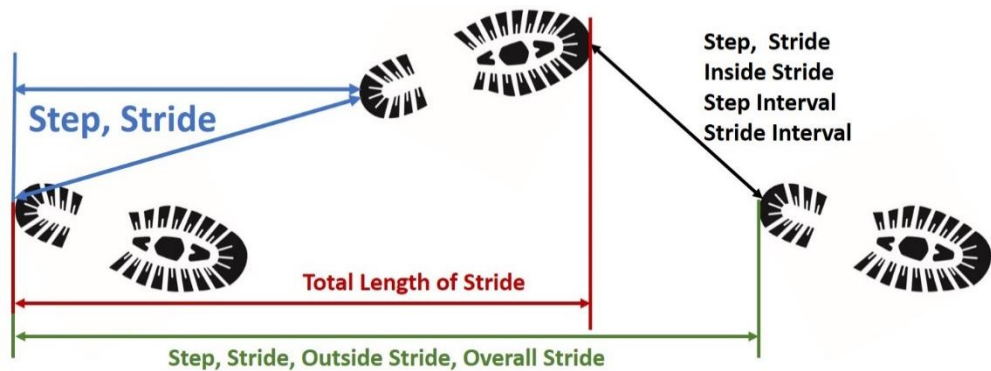


Figure 4. A diagram summarizing the various names for the different lengths between footfalls.

3 STRADDLE

This section presents the three ways of measuring a width of trail that were found in the literature, along with their descriptions.

3.1 Measurement Description

Many of the researched publications described a measurement for the width of a human trail as a dimension that is perpendicular to the direction of travel. Though only three methods to measure this width were found, the terms used to describe this width were more numerous. Each of those three ways involves drawing a line that connects a point at some location of the foot to that same location in the next footfall of the same foot. Those points are either the inner (medial) aspect of the heel (hereafter called ‘Inside’), the center of the heel (hereafter called ‘Middle’), or the most outside (lateral) edge of the whole foot (hereafter called ‘Outside’).

The methods of measuring the width of a bipedal trail begin by creating two lines. One line is drawn for the left ground contact points and another line for the right ground contact points. Each line is drawn parallel to the direction of travel through the selected location for each side. The measurement is the distance from the line for the left ground contact points to the line for the right ground contact points. These two lines are called, respectively, left straddle line and right straddle line (see Figure 8) (Speiden, 2009, 2018a, 2018b, 2023).

As mentioned in three tracking books (Speiden, 2009, 2018a, 2023), the width between the two straddle lines can be positive, zero, or negative. It is positive when the line for the left feet is some distance to the left of the line for the right feet. The width is zero when the two lines overlap each other. The width is negative when the line for the left footfalls lays to the right of the line for the right footfalls (think of a fashion model's runway walk). Many resources did not include a measurement describing the width of a person's trail. Two books by the same author mentioned either two ways (Cunningham, 2016) or all three ways to measure this dimension (Cunningham, 2011).

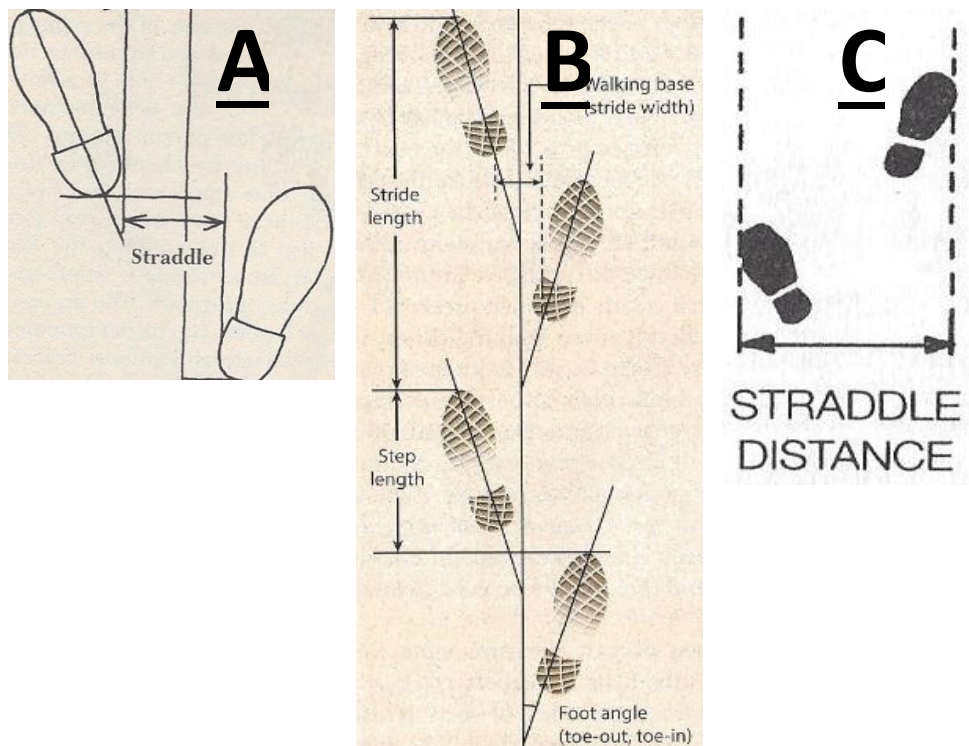


Figure 5. Three diagrams from separate tracking books depicting three ways to measure the width of the track line.

5A Reprinted from *Field Guide to Nature Observation* (p. 259) by T. Brown, Jr., 1983, Berkley Books. Copyright Berkley Books. Reprinted with Permission.

5B Reprinted from *Forensic Footwear Evidence*, (p. 22) CRC Press. Copyright (2017) by CRC Press. Reprinted with permission.

5C Reprinted from *SAS Guide to Tracking* (p. 28) by B. Carss, 2000, Lyons Press. Copyright 2000 by Lyons Press. Reprinted with permission.

3.2 Inside

The narrowest measurement of the three options is made in the inner portions of the track set (see Figure 5A).

Tracking books were the predominant resource (11 (65%) of 17) to practice this way of describing the measurement, almost all used the term “straddle” (for example, Cheney, 2013; Cunningham, 2016; Maxwell, 2016; Stilwell, 2012; Wilson, 2002). Other terms were: “width of straddle” (Diaz, 2013), “step width” or “width of walking base” (O’Sullivan et al., 2019), “stride width” (Hurth, 2012), “width apart” (Abbott, 1964), “heels apart” (Cassidy, 1980), and “distance between heel lines” (Contini et al., 1965). The inside measurement technique is the recommended method, by this paper, because of ease of measurement in the field and lack of influence from other dimensions such as pitch.

3.3 Middle

The middle measurement is typically described as the width between lines drawn through the middle of the heels (see Figure 5B). Seventeen resources conveyed this measurement through the middle of the heels; this finding is equal in number to the quantity of researched resources that measure straddle at the insides of the heels. Gait analysis publications comprised most (76%) of the middle-of-the-road camp.

Of 17 resources that measure from the middle, there were two tracking books (Cunningham, 2011; Taylor & Cooper, 2014), two forensic books from the same author (Bodziak, 2000, 2017), and 13 gait analysis studies (for example, Archbold & Mullarney, 2018; Thompson, 2002; Murray et al., 1966; Murray et al., 1964; Saunders et al., 2004). Seven of the gait analysis sources used the term “stride width” (for example, Archbold & Mullarney, 2018; Chodera & Levell, 1973; Gupta et al., 2016; Levangie & Norkin, 2011; Murray et al., 1964). Other terms used to denote this measurement were “step width” (Saunders et al., 2004; Wall et al., 2000), “straddle” (Cunningham, 2011; Taylor & Cooper, 2014), “walking base” (Kharb et al., 2011; Richards et al., 2012; Thompson, 2002), and “width of base support” (Uustal, n.d.).

3.4 Outside

Three tracking book authors expressed the measurement at the widest part of a set of human tracks. In their writings, these authors used either “trough” (Cunningham, 2016), “straddle distance” (see Figure 5C) (Carss, 2009, 2000, 2008), or “trail width” (Cunningham, 2011; Hull, 2015). Many non-human animal tracking books express this as “trail width” for quadrupeds which is measured at the widest width of a grouping of all four feet (for example, Elbroch et al., 2012; Elbroch, 2019; Lowery, 2013; Rezendes, 1999; Tkaczyk, 2015).

Figure 6 summarizes the measuring locations, widths, and names that were discussed in this section. The biggest differences are the location of the reference lines used for measuring this dimension and the names of the measurements. Tracking books comprised the majority of the resources that

described the inside method of measurement, and gait analysis research comprised the majority of resources that described this measurement via the middle-of-the-heel technique.

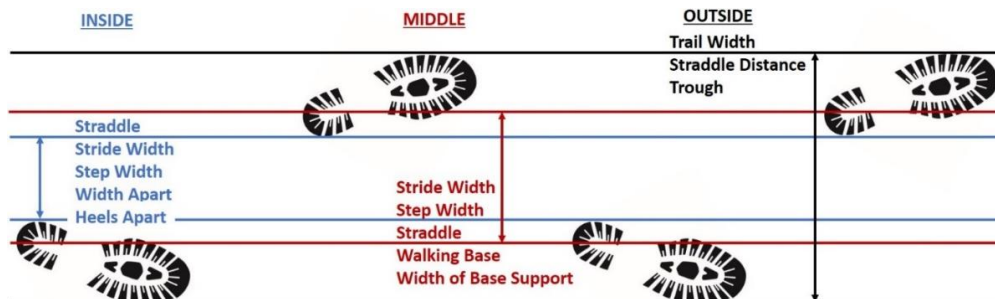


Figure 6. A diagram comparing all three straddle measurement techniques and their various names.

4 FOOT ANGLE

This section presents the two ways of measuring the orientation of footfalls relative to the line of travel as found in the literature. These two techniques involve measuring the position as an angle or a distance.

4.1 Measurement Description

The literature described this measurement as the angle of a footfall (shown as an imaginary line that represents the longitudinal axis or midline of a foot impression) relative to the direction of travel. Less than half (41%) of the 70 cited resources mentioned some form of this measurement.

This dimension can be *positive* (e.g., foot angled out and away from the line of travel – see Figure 7), *zero* (e.g., foot pointed forward along line of travel), or *negative* (e.g., toe pointed inwards).

Although there are a handful of names used to describe the relationship between the angle of footfall and direction of travel, the literature review yielded only two measurement methods. The next two sections detail those discussions.

4.2 As an Angle

Foot angle measurement as an actual angle can be accomplished with a tool called a goniometer. Two tracking books, four forensic books, and ten biomechanical publications described an angular measurement. Authors who diagrammed or described measuring this relationship as an angle most commonly used the term “foot angle” (for example, Bodziak, 2017; Cassidy, 1980; Chodera & Levell, 1973; Gross, 1922; Hurth, 2012), “toe-out” (Ustul, n.d.), or “toe-out angle” (Contini et al., 1965; Kharb et al., 2011; Richards et al., 2012; Whittle, 1991). The term toe-out is an interesting nod to the fact that most humans exhibit a positive angle or toe out while walking. The only other phrase expressing an angle was “pitch angle” (Diaz, 2013).

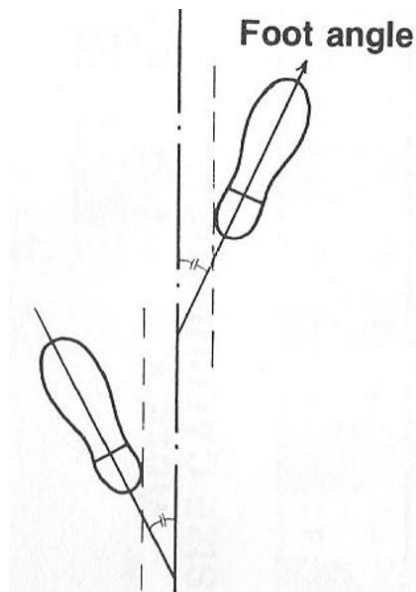


Figure 7. A forensic textbook diagram showing the foot angle measured as an angle. Reprinted with permission from *Footwear Identification*, by M. Cassidy, 1980, Public Relations Branch of the Royal Canadian Mounted Police. P 116.

4.3 As A Length

Another method for measuring the deviation from the line of travel of an imaginary line through the longitudinal axis of the footfall is a distance that can be measured with a tape measure. Eleven tracking books employed this way of measuring that dimension. They predominantly labelled it “pitch” (for example, Cheney, 2013; Maxwell, 2016; Speiden, 2023; Stilwell, 2012; Wilson, 2002) with one exception which uses “external pitch” (Hull, 2015), which is likely recognizing that the majority of humans pitch out.

Pitch was commonly measured as a distance between the aforementioned imaginary longitudinal line at the leading edge of a track and the inner straddle line discussed in section 3.1 (see Figure 8). Only four tracking books distinguished between a right pitch and a left pitch (Speiden, 2009, 2018b, 2018a, 2023). This is the method recommended for trackers due to the ease of measurement in the field with tools already being used for other measurements.

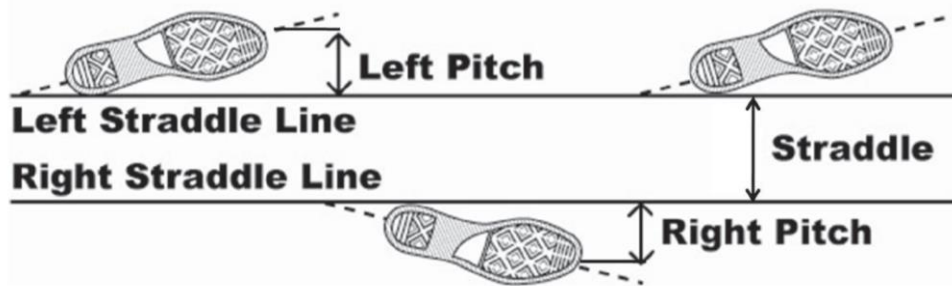


Figure 8. A diagram from a tracking textbook showing the lines used to measure pitch as a distance for each side. Reprinted from *Foundations for Awareness, Signcutting, and Tracking* (p. 47), by R. V. Speiden, 2009 & 2018, Natural Awareness Tracking School, LLC. Copyright 2009 & 2018 by Robert Speiden. Reprinted with permission.

Figure 9 summarizes the measuring methods and names that were discussed in this section. The biggest difference in the 29 works that described this measurement was whether the expression of foot position relative to the line of travel is described and measured as an angle, as was done by 13 gait publications, or measured as a length, as was described in 11 tracking resources.

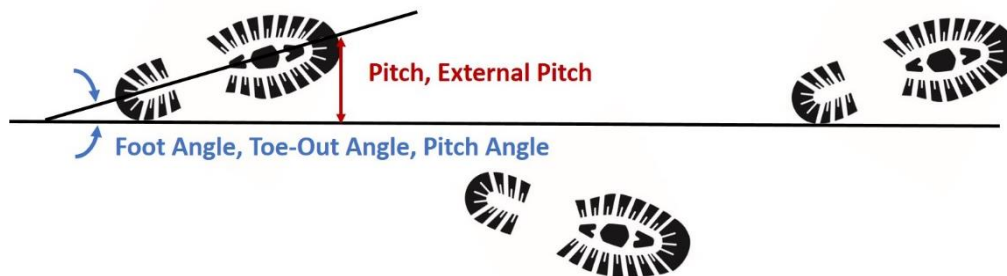


Figure 9. A diagram showing two expressions of ways to measure the orientation of tracks relative to the direction of travel.

Discussion

There are a variety of techniques and names used throughout the body of literature for something as simple as human movement ground contact points. The selection of terms recommended in this paper are drawn from two factors: frequency and convenience. If a term for a dimension was widely used in the literature, it was more likely to be selected for use in the recommendations at the end of this section. If a technique for measuring was more convenient for field applications, that also factored in to the selection and subsequent recommendation of the techniques in the suggested glossary. No trade-specific uniqueness or pattern was discovered in the literature review.

Step Length

A question of whether the distance between subsequent footfalls should be measured independent of straddle was considered with regard to measuring step length. In other words, there are two ways to measure step length. One way is to measure step length as the distance from lines drawn perpendicular to line of travel through a certain point in the footfall. Another way would be to measure directly from one footfall to the next. For a particular distance of footfalls along a direction of travel, wider straddles would increase this measurement. Without being overly concerned about how wide the trail is while taking this measurement, many trackers have found it easier to measure from one track to the next (as shown by the diagonal blue line in Figure 4).

For a scientific study of gait or other movement, gathering data for each dimension independently of the others makes more sense. In gait analysis research, it was more common to depict the distance of step or stride along the direction of travel (horizontal blue line in Figure 4), as opposed to merely one footfall to another (diagonal blue line in Figure 4).

The majority of the researched literature distinguishes step length as the distance from one footfall to the next footfall, and stride length as the distance from one footfall to that same foot contacting the ground again, regardless of the literature background. Human trackers may want to rely on the customary standard of measuring a step length from heel to heel of consecutive footfalls, and measuring stride as the distance from heel strike to heel strike of two tracks in a row created by the same foot. If the heel marks are not available, using the same location in a footfall can substitute for heel marks with the same results for those lengths (e.g., front of toe to front of toe).

Straddle

Research discovered three ways to measure a straddle width. All three versions used straddle lines drawn in different locations. Measurement using lines placed along the outer aspect of the trail would be affected by pitch as well as the spacing between the tracks. That technique was cited by six tracking resources. Measurements using the midline of the tracks would be more difficult to discern and would partially depend on exactly where the straddle lines would be drawn.

The middle measurement technique was cited by 13 gait publications and four others; this comprised the majority of all of the resources that discussed a straddle-type measurement. Measurement of straddle width as the distance between the two straddle lines, as drawn along the inner aspects of the heels, would be independent of other gait dimensions and was discussed by 11 tracking resources. This technique, dubbed the Inner technique, is this paper's recommendation for human trackers.

Pitch

There were two ways to measure pitch discovered in the literature. The majority of the works (13 gait publications, three forensic books and two tracking books)

described the angle method. Tracking books were the only background type to discuss this dimension as a distance, and there were 11 of those. In the field, pitch is easier to measure as a length using a tool that trackers should already carry for other measurements: a tape measure. A tracker could carry a goniometer to measure pitch as an angle if preferred, as long as the method is communicated accurately. Another way to measure pitch as an angle with a tool a tracker should already be carrying is to use a compass to measure the magnetic bearing of the line of travel, then compare that to the magnetic bearing of the centerline of a track...the difference of those would result in the foot angle. All of these measurements can be made for the left and right side of the bipedal track maker.

Contrary to humans, birds typically exhibit a negative angle or toe-in while walking, hence the term “pigeon-toed.” The terms “duck walk” and “duck-footed”, however, have been erroneously used to characterize a human that toes-out because ducks toe-in significantly (even more than pigeons). “Splay-footed” or “toe-out” may be better descriptors for the phenomenon of toeing out.

Suggested Glossary of Gait Measurements for Tracking Humans

Combining field convenience with commonality among industry publications, the following set of measurements are the recommended techniques for describing dimensions of human ground contact points. The first part of these definitions are concise summaries. The superscripted endnotes indicate additional comments included at the end of this glossary section regarding the measurement techniques.

Left Step Length – The distance from the back of the heel of a right footfall to the back of the heel of the next left footfall.^A

Right Step Length – The distance from the back of the heel of a left footfall to the back of the heel of the next right footfall.^A

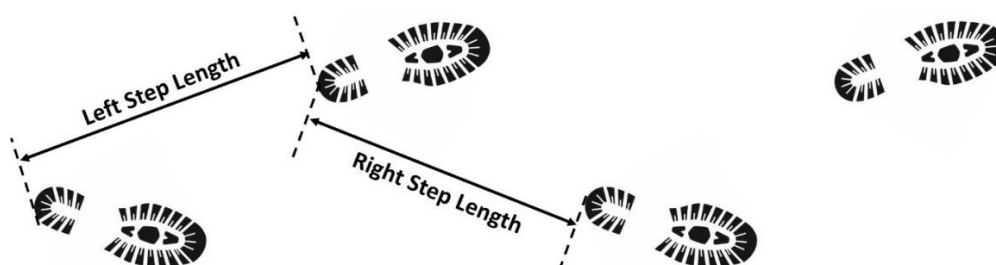


Figure 10. Diagram showing recommended left and right step length measurements.

Left Stride Length – The distance from the back of the heel of a left footfall to the back of the heel of the next left footfall.^A

Right Stride Length – The distance from the back of the heel of a right footfall to the back of the heel of the next right footfall.^A

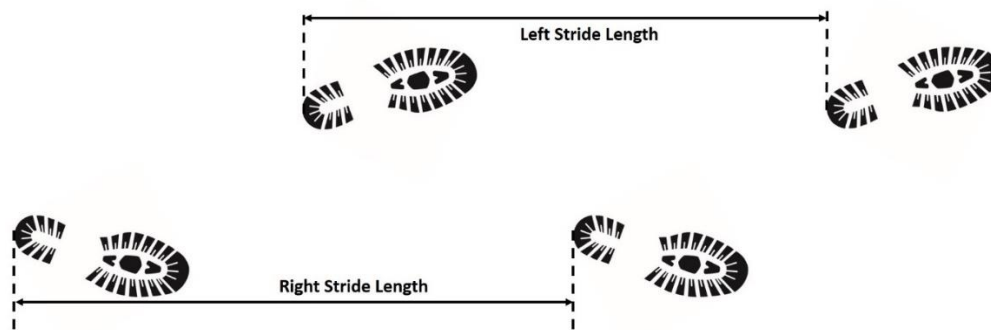


Figure 11. Diagram showing left and right stride length measurements.

Straddle – The width between the right and left straddle lines. Each straddle line is drawn along the medial (inner) aspect of the heel marks of each side of the person (i.e. one straddle line for the right side and one for the left).^B

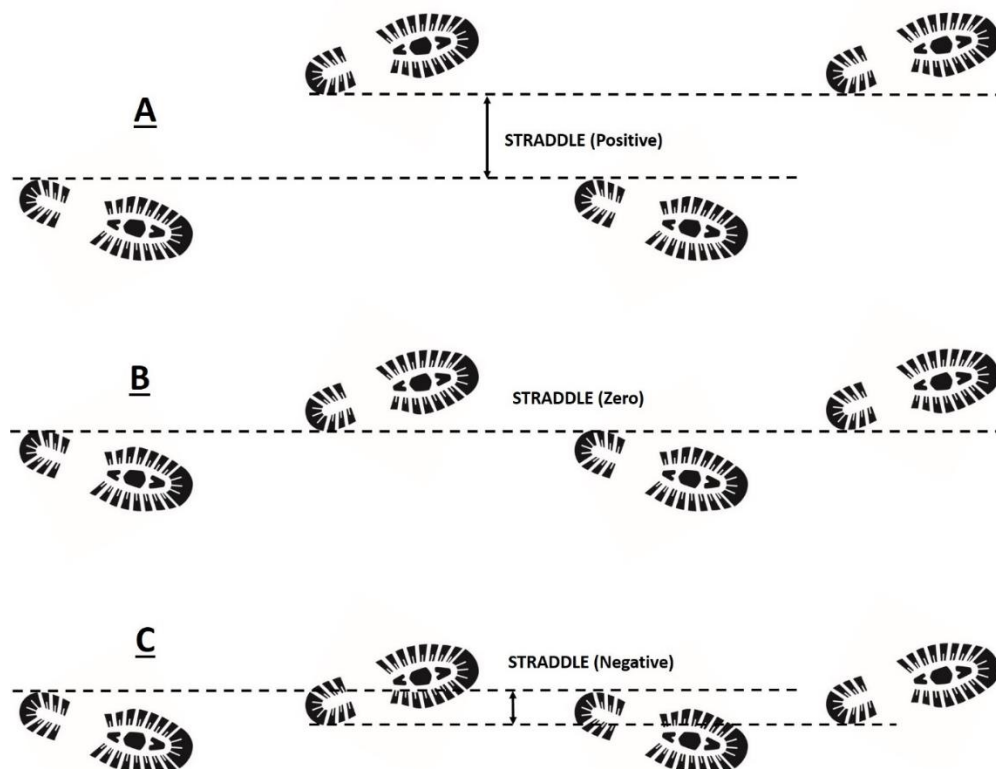


Figure 12. Diagram showing straddle measurement possibilities as positive (A), zero (B), and negative (C).

Left Pitch – The shortest distance from the left straddle line to the anterior aspect of the mid-line of the left foot.^C

Right Pitch – The shortest distance from the right straddle line to the anterior aspect of the mid-line of the right foot.^D

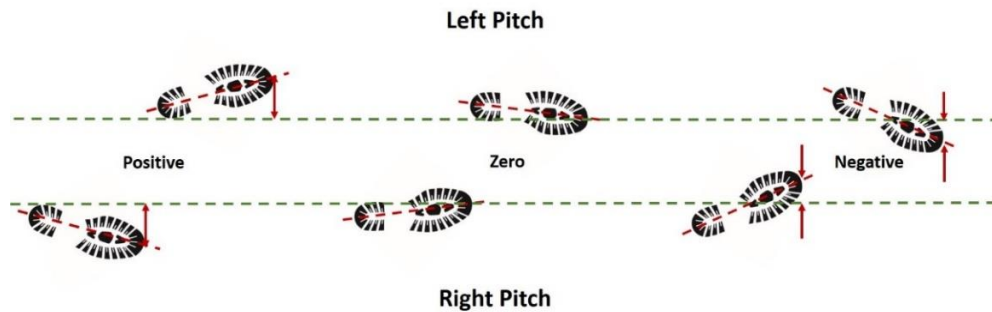


Figure 13. Diagram showing left and right pitch measurement possibilities as positive, zero and negative relative to the straddle lines.

^A As long as the reference point is the same in both footfalls, this distance can also be measured between the same two footfalls at other reference points in both footfalls (e.g., the front of the heel or front of the toe), regardless of whether the person is shod or unshod.

^B This distance is usually positive. If the two straddle lines are on top of each other, it is zero. If the left straddle line is to the right of the right straddle line, the value is negative.

^C This distance is usually positive. If the anterior aspect of the mid-line of the left foot is on the left straddle line, the measurement is zero. If the anterior aspect of the mid-line of the left foot is to the right of the left straddle line, the value is negative.

^D This distance is usually positive. If the anterior aspect of the mid-line of the right foot is on the right straddle line, the measurement is zero. If the anterior aspect of the mid-line of the right foot is to the left of the right straddle line, the value is negative.

Table 1 lists a summary of myriad terms for gait dimensions found in the included literature, and a column of the terms recommended by this manuscript.

Table 1.
Summary of Measurement Descriptions, Commonly Used Terms, and Recommended Terms

<u>Dimension Description</u>	<u>Frequently Used Term(s)</u>	<u>Recommended Term</u>
Difference between direction of travel and direction of foot	Pitch	(Right or Left) PITCH
	Pitch Angle	
	Foot Angle	
	Toe-out Angle	
Distance between footfalls as measured perpendicular to the direction of travel	Straddle	STRADDLE
	Step Width	
	Stride Width	
	Walking Base	
Distance between two consecutive footfalls of both legs	Step	(Right or Left) STEP
	Stride	
Distance between two consecutive footfalls of the same leg	Stride	(Right or Left) STRIDE

Future Research

One of the limitations in this research was the English language. In addition to the history of gait analysis, there are myriad resources considering the study and description of gait in many languages besides English. Including those resources could also bolster this research.

There are other gait characterizations, such as stance/swing phases and contact/impact points, found in the cited resources. These measurements were omitted from this work but would be worthwhile topic for additional research.

Additional resources could be added to this work to provide a more complete picture of the variety and quantity of resources that utilize these measurements. A similar semantic exploration could be compiled for quadruped gaits.

Conclusions

This research explored different ways that 70 resources depicted measurements of a series of human tracks. Publications on human footfalls have been produced for centuries. They include a variety of ways to describe measurements of bipedal contact with the ground. Depictions of recommended human footprint measurements are presented and summarized in Table 1 and Figure 14. SAR trackers' communications of tracking findings should include dimensions of footfalls relative to each other in a series of prints.

Regardless of the technique(s) a tracker chooses to measure a person's gait, method selection and consistency remain important selection factors. A tracker's ability to describe those dimensions is more important than how the distances between and among footfalls of a person they want to follow are measured. As long as the tracker articulates the method used when communicating or receiving ground contact point measurements, other persons should be able to accurately understand the technique(s), and use the same procedure(s) to make any field-observation comparisons.

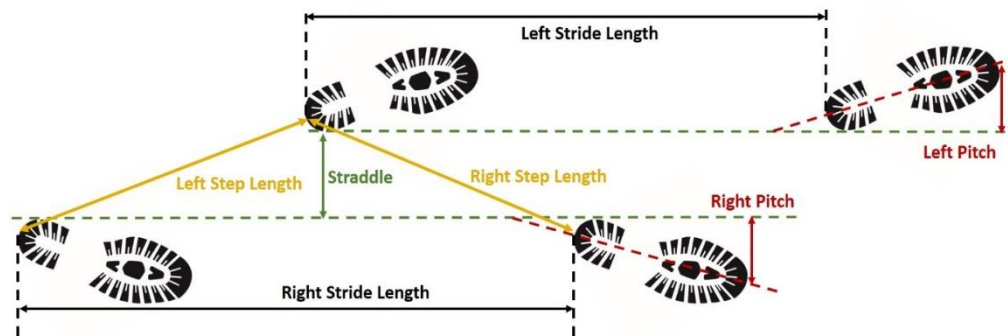


Figure 14. A diagram summarizing recommended gait measurements for human tracks. The colors are used to distinguish different dimensions.

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