Treadmill Exercise

Running or walking up hills causes a dramatic increase in exercise intensity and energy expenditure. Most individuals can relate to this fact through personal experience. Early scientists conducting research in exercise physiology soon realized that field research on running or walking was made complex and detracted from precision due to the translation of distance during the exercise. Basically, it is more difficult to measure responses and obtain samples (e.g. blood) from a subject who is moving over ground, and who can consciously or sub-consciously change their speed and potentially compromise the validity of the research design. Consequently, the motorized treadmill was an early invention dating back to the early 1900's. Such instrumentation revolutionized research into exercise physiology, as now such work could be done in a laboratory under controlled conditions, and increased the variety and accuracy of added measurements that could be made.

Treadmills have now progressed to be of different sizes and applications. For example, the treadmill photograph shown here is the equine treadmill located in the School of Animal and Veterinary Sciences at Charles Sturt University, Wagga Wagga,NSW. In fact, equine exercise physiology is now a well researched discipline within veterinary medicine, as well as the broad fields of basic and comparative physiology.

Walking, jogging and running are by far the most common exercise modes performed for both physical activity and exercise. However, level walking, jogging and running are not suitable for egonometric computations of work and power as there is no accumulated force application against gravity. Sure, the body's center of gravity does oscillate up and down during these activities, but this is a small change and one that is only detectable using sophisticated equipment. Furthermore, such vertical movements are only small and do not compare to the extensive biological work done in moving the body horizontally.

The same concerns apply for any action where there is far greater horizontal then vertical movement of the body. Such added examples are in-line skating, swimming, roller skating, cross country skiing, ice skating, etc.

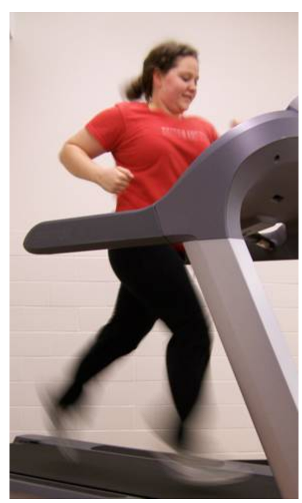

Figure 1. A subject running on a treadmill.

Despite the inability to compute work and power during walking, jogging and running, the use of the **treadmill** (Figure 1) is prevalent within exercise physiology. As you should appreciate, the treadmill allows individuals to walk, jog or run inside in a confined space. With wider and higher performance treadmills, actions such as cross country skiing, skating, or wheel chair locomotion can be performed and researched. For an exercise physiologist, this then allows investigation of the physiology of exercise in a very controlled and safe environment. Consequently, it is important that any student of exercise physiology be fully informed about how the treadmill is used during laboratory exercise testing.

Calculating treadmill speed is easy, as shown in Equation 1.

$$\text{Speed}\left[m/\text{min}\right]=\frac{\text{belt length}\left[m\right]\times\text{belt revolutions}\left[number\right]}{\text{time}\left[\text{min}\right]}$$ Equation 1

Calculating treadmill grade is a little more involved, as the unit for treadmill grade is **%grade**, which as you will see is a modification of the ratio between rise over run of the treadmill (vertical height gain relative to horizontal distance). I have illustrated this concept in Figure 2.

The mathematical expression of %grade is given in Equation 2. As it is more accurate to measure belt lengths (hypotenuse) and vertical height change (rise) for a given increment in slope of a treadmill, computation of %grade is best undertaken by first calculating the treadmill angle using trigonometry.

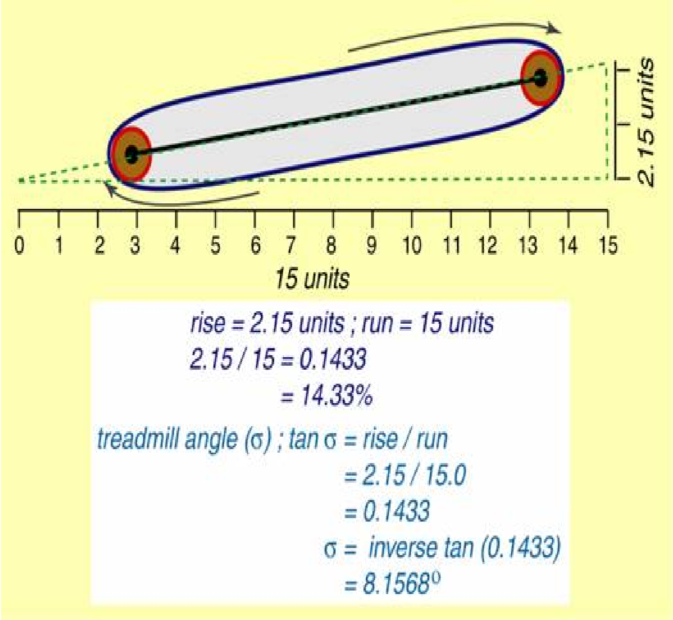

Figure 2. Diagram for revealing the trigonometry involved in understanding the %grade unit of treadmill angle or slope. ***(Note, the arrows should be pointing in the opposite directions!)***

$$treadmill\ angle\left[^\circ\right]=\sigma;\ \sin\sigma=rise/hypotenuse;\ \sigma=inverse\ sin\left(rise/hypotenuse\right);$$
$$\tan\sigma=rise/run$$ Equation 2
$$if\ \ \sigma=5^\circ;\ then\ \tan\sigma=0.0875;\ \%grade=\tan\sigma\times100=8.75\%=1:11.43\ slope\ ratio$$

To give %grade some practicality, note that a 45 degree angle has a %grade of 100% (1:1 slope). In addition, those of you who pay attention during your road trips might recall signs alongside the road in hilly terrain that displayed things like, "*Caution, 5% Downhill Grade Next 1.5 Miles*". This means that for every 100 m of horizontal distance, you would go down 5 m. Cars and trucks slow down up steep grades, because they are doing added work, with the added work equating to the product of their weight and the vertical distance traveled. The heavier the vehicle, the greater the added work of up-hill driving and down-hill braking. Most large vehicles have larger engines, so this makes the impact of the hill less on vehicle speed, but the fuel consumption of driving is appreciably greater!

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Figure 3. Lombard Street, San Francisco, California.

%grade	tan σ	Angle (°)
1	0.01	**0.57**
2	0.02	**1.15**
3	0.03	**1.72**
4	0.04	**2.29**
5	0.05	**2.86**
6	0.06	**3.43**
7	0.07	**4.00**
8	0.08	**4.57**
9	0.09	**5.14**
10	0.10	**5.70**
11	0.11	**6.08**
12	0.12	**6.84**
13	0.13	**7.40**
14	0.14	**7.97**
15	0.15	**8.53**
16	0.16	**9.09**
17	0.17	**9.65**
18	0.18	**10.20**
19	0.19	**10.76**
20	0.20	**11.31**

Note that **Lombard Street** of San Francisco (Figure 3), the most crooked street in the world, has an average %grade (bottom going up) of 16%. Russian Hill, where Lombard Street winds down, has an average slope of 27%; hence the need for the windy street! The road with the greatest slope in the world of 38% is **Baldwin Street**, Dunedin, New Zealand (Figure 4).

Data for %grade, tan σ and treadmill angle (σ) are provided in Table 1.

Figure 4. Baldwin Street, Dunedin, New Zealand. The world's steepest street.

Glossary Words

Treadmill Motorized device that is used to allow stationary walking and running, as well as such exercise modes as skating, skiing, roller-blading, wheel chair movement, etc.

%grade the tan of an angle, expressed as a percent. Also equal to the vertical rise over the horizontal run of a slope, expressed as a percent.

Lombard Street The world's windiest road, located in San Francisco, U.S.A.

Baldwin Street The world's most steep (highest slope) road, located in Dunedin, New Zealand.