

A Double Under Needs Four Times the Height of a Single, and Turning the Rope Twice as Fast Brings It Back to the Same Height

— Turning a rope ω times a second and passing it under the feet k times per jump requires the feet to be off the ground for k/ω seconds, and a jump height of $g(k/\omega)^2/8$ — the separator is whether one asks about jumping power or arm speed — [Paper 881]

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Abstract

It is easy to assume that failing a double under means not jumping hard enough. This paper counts how much height each number of passes needs, side by side with how fast the rope is turned. No new theorem or law is claimed. First, the height needed grows with the square of the number of passes: at 3 turns a second, a single needs **0.136250** m, a double **0.545000** m and a triple **1.226250** m, four and nine times as much (Section 2). Second, and this is the core. Turning twice as fast lets a double under use the height of a single: at 6 turns a second, a double needs **0.136250** m, the same as a single at 3 turns a second (Section 2). Third, time off the ground matches the formula. Following jumps of 0.05 to 0.40 m in fine steps gave times matching $2\sqrt{2h/g}$ within 2×10^{-5} seconds (Section 3). Fourth, a fixed height caps the number of singles: at 10 cm the feet are off the ground for **0.285569** seconds, allowing at most **210.107116** singles a minute (Section 3). Fifth, a double at the same height needs twice the arm speed: staying at 10 cm requires **7.003571** turns a second (Section 3). Sixth, the separator is whether one asks about jumping power or arm speed: the height needed grows with the square of the passes and falls with the square of the turning speed, so doubling arm speed does as much as quadrupling the height (Section 4). **Keywords:** jump rope, double under, time aloft, jump height, turning speed.

Scope of this paper (scope note): No new theorem or law is claimed: the relation $h = gt^2/8$ between time aloft and height for a vertical jump is a standard formula of mechanics.No real records are claimed: turning speeds and heights are model values matching no athlete’s record.Ground contact is not included: time from landing to take-off, rope slack and air resistance are not included.No training is recommended: how to practise is not stated.Relation to earlier papers: Paper 380 showed that the limit on running speed is not how fast the legs move but how hard the ground is pushed. This paper stands beside it. There, how hard the ground is pushed set the limit. Here, jump height and the arm speed turning the rope share the height needed.What is added is laying out the heights for singles, doubles and triples at four turning speeds, matching finely stepped time aloft against the formula, finding the cap on singles and the speed needed for a double at 10 cm, and placing the separator on jumping power versus arm speed.

1. Notation and the Question

Setting: a rope is turned ω times a second and passes under the feet k times during one jump.Let t be the time the feet are off the ground, h the jump height, and $g = 9.81 \text{ m/s}^2$.

$$t = \frac{k}{\omega}, \quad h = \frac{gt^2}{8} = \frac{g}{8}\left(\frac{k}{\omega}\right)^2$$

Ground contact time, rope slack and air resistance are not included.Time aloft was obtained two ways, from the formula and by following the jump in steps of 10^{-5} seconds.

Question: how high must one jump for a double under?

2. Height Needed per Number of Passes

Computation 2.1: for each turning speed ω , the heights needed for single, double and triple passes were computed.

ω (turns/s)	single (m)	double (m)	triple (m)
2	0.306563	1.226250	2.759062
3	0.136250	0.545000	1.226250
4	0.076641	0.306563	0.689766
6	0.034062	0.136250	0.306563

Observation 2.2

the height needed grows with the square of the number of passes. At every turning speed, a double needed 4 times and a triple 9 times the height of a single: time off the ground grows in proportion to the passes, but the height needed for that time grows with its square.

Observation 2.3

this is the core. Turning twice as fast lets a double under use the height of a single. The 0.136250 m needed for a double at 6 turns a second equals the height for a single at 3 turns a second: for the same k , doubling the turning speed from 3 to 6 cut the height needed to a quarter.

3. A 10 cm Jump

Computation 3.1: for each height, time aloft followed in steps was compared with the formula.

height (m)	stepped time (s)	formula $2\sqrt{2h/g}$ (s)
0.05	0.201930	0.201928
0.10	0.285570	0.285569
0.20	0.403860	0.403855
0.40	0.571140	0.571137

Observation 3.2

a fixed height sets the count and the turning speed needed. At 10 cm the feet are off the ground for 0.285569 seconds, so singles are capped at 3.501785 a second, 210.107116 a minute: a double at the same height needs 7.003571 turns a second. The stepped times matched the formula within 2×10^{-5} seconds at all four heights.

4. The Separator

Observation 4.1

the separator is whether one asks about jumping power or arm speed. The height needed is proportional to $(k/\omega)^2$: doubling the passes k leaves the ratio unchanged if the turning speed ω is also doubled. Whether a double under lacks jumping power or arm speed depends on which side of this ratio is moved.

Observation 4.2

placed beside Paper 380.380 showed that the limit on running speed is not how fast the legs move but how hard the ground is pushed. There, pushing force alone set the limit. Here, jump height and arm speed share the height needed, and raising either works equally.

Observation 4.3

what is not said. Real athletes' records, ground contact time, rope slack and training methods are not treated. What is shown is that a double needs four times the height of a single, falling with the square of turning speed.

5. Census and Closing

1. $h = g(k/\omega)^2/8$ (Section 1): **square of the time.**
2. single at 3 turns/s: **0.136250 m** (Computation 2.1): **the baseline.**
3. double: **0.545000 m** (Computation 2.1): **four times.**
4. triple: **1.226250 m** (Computation 2.1): **nine times.**
5. double at 6 turns/s: **0.136250 m** (Observation 2.3): **the core.**
6. stepped time matches the formula (Observation 3.2): **within 2×10^{-5} s.**
7. **0.285569 s at 10 cm** (Computation 3.1): **time off the ground.**
8. singles capped at **210.107116 a minute** (Observation 3.2): **set by height.**
9. double needs **7.003571 turns/s** (Observation 3.2): **at the same height.**
10. jumping power, or arm speed (Observation 4.1): **the separator; Paper 380.**

Closing: A double under needs four times the height of a single, and turning the rope twice as fast brings it back to the same height. At 3 turns a second a single needs 0.136250 m and a double 0.545000 m, and at 6 turns a second a double needs only 0.136250 m, because the height needed grows with the square of the passes and falls with the square of the turning speed. A 10 cm jump keeps the feet off the ground for 0.285569 seconds, capping singles at 210.107116 a minute, and a double at that height needs 7.003571 turns a second: doubling arm speed does as much as quadrupling jump height. Placed among the earlier papers: beside Paper 380's "the limit is not pushing the ground hard enough", we placed that jump height and arm speed share the height needed. To be honest: ground contact time, rope slack and air resistance are not included.

References

1. Halliday, D., Resnick, R., & Walker, J. (2014). *Fundamentals of Physics* (10th ed.). Wiley.
 2. Yamagishi, Y. (2026). *The Limit on Running Speed Is Not How Fast the Legs Move but How Hard the Ground Is Pushed* [Paper 380]. YOI: <https://www.yamagishiyuuki.com/yoi/380>; DOI: 10.5281/zenodo.22698815
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