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How physically feasible is the *Minus Tempo* attack in volleyball?

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Abstract
In the popular manga and TV show Haikyuu, two volleyball players named Hinata and Kageyama invent their own signature move known as the minus tempo attack. This attack focuses on the chemistry and skills of the two players and allowed them to score many points. This paper investigates the feasibility of the minus tempo attack within a real-life scenario using Olympic level volleyball players. The required velocity of the set was calculated to be approximately 8.47 ms^{-1}, which was physically feasible; however, the synchronisation required between the setter and the hitter pushes the limits of elite human reaction times.

Keywords: Manga/*TV; Physics; Mechanics; Haikyuu; Volleyball; Minus Tempo Attack*

Introduction
The *minus tempo attack* is an offensive play that originates from the TV show "Haikyuu". It is a signature move that was developed by the setter, Tobio Kageyama and middle blocker, Shoyo Hinata. The minus tempo attack is when the hitter initiates their jump and their swing before the setter releases the ball. The minus tempo attack can be broken down into the jump of the hitter, the travelling of the ball and the set from the setter.

The Jump of the Hitter
To determine the feasibility of the minus tempo attack, the first constraint that we would need to consider is the time taken for the hitter to reach a height to which the ball can be struck above the net. Typically, Olympic level hitters aim to spike the ball at the pinnacle of their maximum vertical jump as it allows them to generate the greatest downward angle to generate the most power, increasing their chances of beating their opposition's block. Due to this, we will assume the ball is spiked at the maximum vertical jump of the hitter. The maximum height of the hitter can be calculated using the equation [1]:

$$h = \frac{v_0^2}{2g}, \quad (Eq^n\ 1)$$

which can be rearranged to:

$$v_0 = \sqrt{2gh},$$

to give the initial vertical velocity required. This equation is for constant acceleration, with acceleration being due to gravity.

We will assume the average maximum vertical jump height of an elite male volleyball hitter, which is 0.85 m [2].

$$v_0 = \sqrt{2(9.81)(0.85)} = 4.08\ ms^{-1}$$

Therefore, the time taken to reach the peak of their jump can be derived from the equation [3]:

$$v = v_O + at \quad (Eq^n\ 2)$$

As $a = -g$ for vertical motion under gravity and $v = 0$ at the top of the jump, we can rewrite the equation and use it to calculate the time.

$$t = \frac{v_O}{g}$$
$$t = \frac{4.08}{9.81} \approx 0.42\ s$$

In this scenario, for the completion of the minus tempo attack the setter must therefore deliver the ball to the hitter 0.42 s after the hitter leaves the ground such that the ball reaches the hitter's contact point at their maximum height. The

required set speed will be calculated later in this paper.

Modelling an Attacking Scenario

To further evaluate the feasibility of the minus tempo attack we can model an attacking scenario based on typical elite volleyball play. The average height of Olympic male volleyball hitters is 2.045 m with a standing reach of 2.5 m [4]. Using this and the maximum vertical jump height mentioned previously, the spike contact height can be calculated by:

$$h = 2.5 + 0.85 = 3.35\,m$$

The average height of an Olympic male setter is 1.92 m resulting in the ball being released at an assumed height of 2.3 m as the setter would have their hands raised above their head when setting [5].

For simplicity, we will assume the setter and hitter are 3 m apart as well as being horizontally parallel to each other. In addition to this we will assume the spike clears the net height of 2.43 m [6] as the hitter reaches a spiking height of 3.35 m and by assuming the two players are right next to the net. Using a spike height of 3.35 m, a set release height of 2.3 m, a horizontal distance of 3 m between the two players and a required ball delivery time of ≤ 0.42 s, we can calculate the minimum required velocity that the ball must be set by to reach the hitter at their contact point. The horizontal velocity can be calculated using [7]:

$$v = \frac{d}{t}, \quad (Eq^n\,3)$$

$$v_x = \frac{3}{0.42} \approx 7.14\,ms^{-1}.$$

The vertical velocity can be calculated using [8]:

$$y = h + v_y t - \frac{1}{2}gt^2, \quad (Eq^n\,4)$$

which can be rearranged to find the vertical velocity:

$$v_y = \frac{y - h + \frac{1}{2}gt^2}{t}$$

$$v_y = \frac{3.35 - 2.3 + \frac{1}{2}(9.81)(0.42)^2}{0.42} \approx 4.56\,ms^{-1}.$$

Finally, the total velocity can be calculated using [8]:

$$v = \sqrt{v_x^2 + v_y^2} \quad (Eq^n\,5)$$

$$v = \sqrt{7.14^2 + 4.56^2} \approx 8.47\,ms^{-1}.$$

This velocity is feasible as Olympic male attackers can spike the ball at speeds of around 30-35 ms^{-1} [9]. Even though this is specifically for when they are focused on spiking instead of setting, it still showcases the required velocity needed for the model is possible.

Synchronization

The feasibility of the minus tempo attack also depends on the precision of the timing between the setter and the hitter. As the hitter's vertical velocity approaches zero and they reach their maximum jump height, there is an effective spike window in which the hitter can make successful contact with the ball. In this model, if a realistic approximation of this window was taken to be ±0.05 s (allowing for a time tolerance of 0.10 s), this value would directly correspond to the temporal error allowed for the setter when delivering the set as the ball's flight time is fixed once it leaves the setter's hands. Reaction times of elite athletes can be around 0.133-0.167 s [10]. This shows that the synchronization required for the minus tempo attack lies near the limits of human coordination. Consequently, the setter and the hitter would have to reach synchronization levels that can only vary by the order of tens of milliseconds, which is highly challenging. It would require a substantial amount of training and practice to develop the skills and chemistry between the two players. It is important to recognise that the ±0.05 s effective spike window is an approximation, a more precise value could be obtained through future experimental analysis using motion-tracking of elite volleyball gameplay.

Conclusion

Physically, as the results show, the ball can be delivered to a hitter's contact point within the required time under realistic volleyball conditions, the minus tempo attack is feasible. However, this move requires extreme precision (within milliseconds) that cannot be achieved through reaction time alone, but also anticipation, which would only be achievable through rigorous training and would be unlikely to be reproduced consistently in a real game.

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