Mitotic Spindle as Complex Structure: Relation Between Spindle Size and Energy Distribution

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Summary

A purpose of complex subcellular structure named mitotic spindle is to ensure equal division of genetic material during cell division process. Proper functioning of this structure is very important for physiological functioning of tissue and organs. Narrow and long mitotic spindle as well as wide and short are indicative for some mitotic spindle disorders [2, 5]. Cell size can also affect mitotic spindle size [1].

We came to an idea to make a simple biomechanical model of this complex structure [3]. The oscillatory behavior of this model is based on dynamics of coupled systems [4]. Each element in the model has its mechanical counterpart: microtubules are standard light visco-elastic elements, homologue chromosomes are mass particles that are interconnected with standard light massless elastic spring.

In this model, mitotic spindle is presented as a system of coupled oscillators [4] where one oscillatory pair consists of a centrosome, a microtubule and a related chromosome and these are interconnected with their homologous pairs. Centrosomes are presented as mass particles that represent two rheonomic centers of oscillations.

The aim of this work was to study how different spindle size-spindle angle affects the energy of pairs of homologue chromosomes in the system of mitotic spindle during metaphase. The analyses were done through mechanical oscillatory model of mitotic spindle [3].

For numerical analysis we considered forced oscillations in linearized system for tree cases when mitotic spindle size-angle are: $\pi/3$, $\pi/2$ and $2\pi/3$ (narrow, normal and wide respectively) when homologue chromosomes with heavier masses are located in the central zone of metaphase equatorial plane. Data for numerical analysis (chromosomal mass, rigidity of eukaryote metaphase chromosomes, rigidity for microtubules at 37° C, centrosome mass, centrosome amplitude oscillations, centrosome circular frequency) were taken from the literature.

Analytical expressions for potential and kinetic energy as well as for total mechanical energy of oscillating pair of homologues chromosomes are given.

According to the model total mechanical energy of oscillating pair of homologue chromosomes under forced regime of oscillations has oscillatory character. When chromosomes with heavier masses are position in the central zone of mitotic spindle total mechanical energy is lower in the central zone of mitotic spindle. Spindle size affects total mechanical energy of each homolog chromosome pair. Total mechanical energy for each homologue chromosome pair increases with mitotic spindle size-angle. This approach could be useful for understanding mitotic spindle size disorders.

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